ESSENTIALS

of

MEDICAL ELECTRICITY

FOR MEDICAL STUDENTS AND NURSES

By

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TO

MY MOTHER

THESE PAGES ARE AFFECTIONATELY

DEDICATED

PREFACE

It has been the purpose of the author to write a brief manual on electrotherapy in such simplified terms as to make it serviceable for first instruction, and yet complete enough in the scientific basis of medical electricity to cover the main fundamental principles of its therapeutic application. It is an elementary text rather than a treatise; however, a knowledge of elementary physics is a necessary prerequisite.

The teacher will find it necessary to add much oral instruction, and, above all, to use and dissect or construct before the class electric appliances and apparatus, or, better, make it a laboratory course and require such work of the student. Physiologic effects should be demonstrated and the student thoroughly drilled in the various therapeutic applications.

To each of those chapters the author has thought suitable for nurses a short list of review questions has been appended.

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MEDICAL ELECTRICITY

CHAPTER I

INTRODUCTION

THE use of electricity in medical practice dates from the time of Benjamin Franklin. Like the beginnings of nearly all forms of therapy, electricity was first used in a very empirical way, and even in later years, when the physiologic basis of its effects were being worked out, grossly exaggerated claims were made for its therapeutic value, and, unfortunately, are still made by many who have taken up the exclusive practice of electrotherapy.

Like many good things, it has suffered most at the hands of its would-be friends. Electrotherapy is a very valuable branch of physiologic therapy, but its field of usefulness is not large, and many effects which are produced by it can be better secured in other ways. The mystery which in the public mind surrounds all forms of electricity makes it an easy vehicle for decep-

tion. Because of this, it has been seized upon by quacks and charlatans for mercenary purposes. While very much still remains unknown about electricity, yet, if it is to be used scientifically, its application must be based upon a broad experience, balanced by a knowledge of well-authenticated physiologic effects.

Electricity is not an all-vitalizing force. As far as body electricity is concerned, it is not a cause, but rather an outgrowth or accompaniment of its various activities. The human body is a great chemical cell, or, more accurately speaking, an orderly arrangement of many cells, which, as a result of their multitudinous metabolic and other activities, produce various electric currents and electric manifestations.

If a common galvanic cell were out of order we would not seek to restore its usefulness by treating it from another cell or battery, but would at once set to work to clean up its elements, renew its exciting fluid, or remove dirt and other obstructions. Just so with the human body, if its cells no longer manifest their normal activities, the cell materials must be renewed by new chemicals, *i. e.*, proper food; obstructions and perversions of function cleared up by measures which have a demonstrated worth in each case. Except in various forms of paralysis, electricity should be more an adjunct to other treatment than the main therapeutic agent used. It is the purpose of the following pages to point out these principal conditions in which electricity is useful, and

to elucidate its physiologic and therapeutic effects in such cases.

Electric manifestations are divided into two general classes—dynamic and static.

"Dynamic electricity may be regarded as electricity in motion, while static electricity is electricity at rest. Dynamic electricity is known chiefly by the effect of its transmission through conducting paths, and static electricity chiefly by its effects as a stationary charge or as a disruptive discharge through non-conducting paths."[1]

"Dynamic electricity is really akin to mechanic motion, while static electricity is equivalent to a tendency to motion produced by an elevated position."

The galvanic current is the purest manifestation of dynamic electricity.

There are five forms of electricity which are made use of in therapeutics. These are galvanic, static, faradic, sinusoidal, and high frequency. The latter three are derived forms. The characteristics of each will be considered in their proper place, together with the methods of production and apparatus necessary. The following list shows briefly the methods by which each is produced:

Galvanic—chemical action, induction (dynamo).

Faradic—induction (step-up transformer).

[1] Tousey, Medical Electricity, Röntgen-Rays, and Radium, *2d Ed.*, p. 71 (W. B. Saunders Company).

Sinusoidal—induction (dynamo).

Static—friction, induction (static machine).

High frequency—induction (step-up transformer).

To intelligently apply these forms of electricity the physician or nurse must obtain a thorough understanding of the physics of each, and the manner in which the body responds to their application.

CHAPTER II

GALVANIC ELECTRICITY—THE CELLS

A GALVANIC current may be produced by a direct-current dynamo, from an alternating current by a current rectifier, or (best of all for medical purposes) by galvanic cells, *i. e.*, by chemical action. It is somewhat outside the province of this work to discuss the first two. The third method is very commonly used, and so should be well understood if the best results are to be obtained.

In generating a galvanic current for medical purposes some form of sal ammoniac cell is most practical. For small or portable batteries the dry cell may be used, but for all-round use the wet cell is the best. In this—the Leclanché cell (Fig. 1)—the elements are carbon and zinc, and the exciting fluid is a solution of sal ammoniac (ammonium chlorid—NH_4Cl). The 3-pint jar should be filled about two-thirds full with warm water containing 5½ ounces of ammonium chlorid.

The ammonium chlorid acts upon the zinc, producing zinc chlorid ($ZnCl_2$). Chemical changes are always accompanied by electric disturbances, and hence when the outer ends of the zinc and carbon elements are con-

nected a flow of electricity occurs (Fig. 2). The zinc element is finally eaten away and must be replaced. The

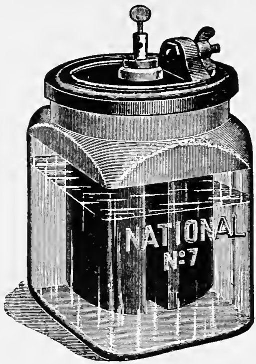

Fig. 1.—Leclanché cell.

exciting fluid does not act upon the carbon. It is at the surface of the zinc element that the chemical changes occur. Here the electric equilibrium is disturbed, and

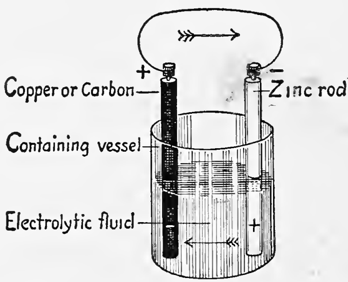

Fig. 2.—Galvanic (or voltaic) cell.

hence from here the electric current flows. Just as in the case of a lift-pump operated in a tank of water

(Fig. 3), the level of the water is disturbed, and the raised water flows from the spout of the pump back again to the lower level; so in the galvanic cell, the current is said to flow from the point of disturbance on the surface of the immersed part of the zinc to the immersed end of the carbon element. For this reason the zinc is called the *positive element* and the carbon the *negative element.*

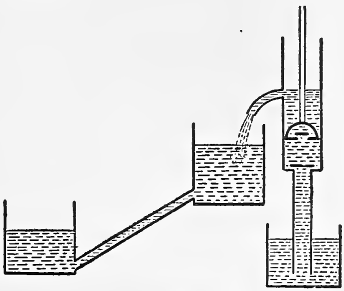

Fig. 3.—The lift-pump, illustrating effect of chemical action in disturbing electric level. Difference of water level compared to potential.

Outside the cell, when the free ends of the carbon and zinc are connected by a copper wire, the circuit is completed and the flow is from carbon to zinc—*i. e.*, the carbon constitutes the *positive pole* and the zinc the *negative pole.* If the poles are not connected the electric disturbance occurs just the same because of the chemical action, but it is not confined, and, no channel being provided, there is no flow or current produced.

In setting up the cell for use it is well to dip the mouth of the jar in melted paraffin before filling, so

as to prevent wetting of other parts and short-circuiting. The hard-rubber cap of the jar may also be dipped in paraffin for the same purpose. The binding screw and washers at the outer end of the elements which attach the wires to the elements, and also the attached ends of the wires, must be bright and clean and tightly fastened, for perfect contact is necessary to insure a current. Electricity cannot be had without scrupulous cleanliness, a rule which applies also to all parts of the galvanic battery.

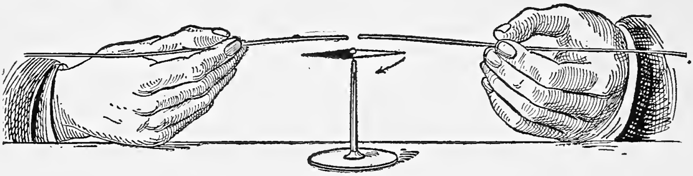

Fig. 4.—A simple galvanometer.

To determine the presence of an electric current in the wires from a galvanic cell recourse may be had to a galvanometer or a milliamperemeter, the presence of a current being determined by a deflection of the needle. A simple galvanometer may be made by using an ordinary compass. Place this so that the N on the card is directly under the north pole of the needle. Place one wire down over the face of the compass parallel with the needle, and touch its unattached end with the end of the wire from the other pole (Fig. 4). If a current is passing the needle will be deflected from its resting position, and the side to which it is deflected will be

governed by the direction of the current. To determine the direction of the current from the behavior of the needle, place the right hand, palm down, over the wire, with the fingers parallel with it and the thumb on the side toward which the north pole is deflected (Fig. 5). With the hand in this position the index-finger will point in the direction the current is flowing. This rule might appropriately be called the "rule of thumb." A more delicate galvanometer may be made by wrapping several turns of wire about the compass at right angles to the needle.

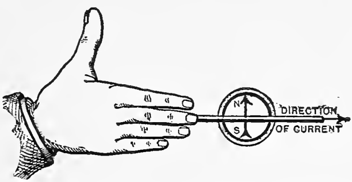

Fig. 5.—"Rule of thumb." (Gage, "Principles of Physics.")

If a stick of copper and another of zinc are immersed in sal ammoniac solution, or, better, in dilute sulphuric acid (H_2SO_4), and the outer ends connected, a feeble current may be detected. If two sticks of zinc or two of copper are used, no current at all will be produced. It is necessary that the elements be dissimilar, *i. e.*, that one be acted upon to a greater extent than the other. The greater the dissimilarity, the stronger the current.

From the preceding discussion we may sum up the essentials of a galvanic (or voltaic) cell as three, viz.:

(1) two dissimilar elements; (2) an exciting fluid, and (3) a circuit.

Polarization.—When a cell has been in use some time the products of chemical action collect on the elements, and either hinder further action or prevent the passage of the electric current. This is termed "polarization." The readiness with which a cell polarizes, and the

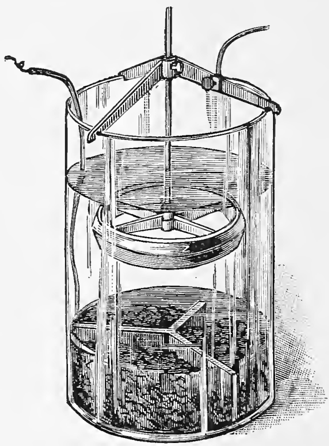

Fig. 6.—Gravity cell. (Gage, "Principles of Physics.")

rapidity with which it recovers itself, determines, to a large extent, its use.

For example, the dry cell, which is used so much for door-bells and similar purposes, polarizes very quickly, and so cannot be used where a continuous current is wanted for a long time. But, while it polarizes so quickly, it likewise recovers itself very quickly, hence its usefulness for the purposes mentioned.

The Leclanché cell does not readily polarize, and so can be used for a long time without replenishing, provided it be not used continuously. For this reason it is the best cell for medical purposes, since it requires so little attention. The gravity cell (Fig. 6) hardly polarizes at all, and so is used for telegraphy, where almost a constant current is needed.

Fig. 7.—Dry cell.

In the sal ammoniac cell (either wet or dry) polarization is due to the collection of hydrogen gas on the carbon element. The gas obstructs the passage of the electric current. To prevent this polarization the carbon element (in the wet cell) is often made in the form of a hollow cylinder, which is packed with granular manganese dioxid. This absorbs the hydrogen as fast as it is formed.

In the dry cell (Fig. 7) the manganese dioxid is mixed

with the starch paste which contains the sal ammoniac —the active part of the mixture. The container is made of zinc, and so acts as the positive element.

In the Grenet or Fuller's cell (Fig. 8) polarization is caused chiefly by the collection of the products of chemical action on the zinc plate.

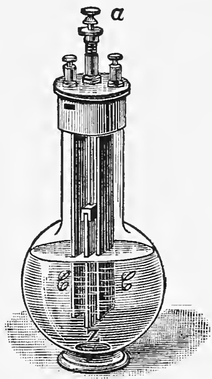

Fig. 8.—Grenet cell: *a*, Brass rod; *c*, *c*, carbon plates; *z*, zinc plate. (Gage, "Principles of Physics.")

In this cell the exciting fluid is made up as follows:

Potassium bichromate	4 ounces.
Mercury bisulphate	2 drams.
Water	1 pint.
Sulphuric acid	3 ounces.

The elements are carbon and zinc.

Polarization is prevented by the bisulphate of mercury, which forms an amalgam with the zinc, and so keeps it bright and clean like a penny rubbed with quicksilver. The action of the sulphuric acid is so

energetic that the zinc plate must be removed when the cell is not in use.

Polarization is the prevention of the passage of the electric current by the collection of products of chemical decomposition on the elements.

Ohm's Law.—When it comes to the practical use of electricity there are three things that must be taken into account—viz.: the electromotive force, the resist-

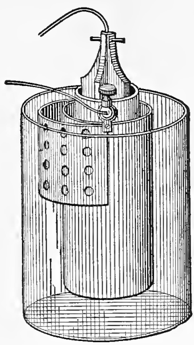

Fig. 9.—Daniell cell. (Gage, "Principles of Physics.")

ance or friction, and the current. The electromotive force (E. or E. M. F.) is the generating power, the strength of the push, the force with which the current is generated. With a galvanic cell it is quite largely in proportion to the vigor of the chemical action. The Daniell cell (Fig. 9) is taken as the basis of electromotive force, and is, therefore, said to possess a strength of one unit of electromotive force. This unit is called a *volt*. The Daniell cell is a cell of a certain standard

size and strength of exciting fluid. A Leclanché cell possesses an electromotive force of about $1\frac{1}{2}$ volts.

In a circuit of any material the conductors are not perfect conductors, but offer a certain amount of resistance to the passage of the current. Substances are good or poor conductors, according as they offer little or much resistance. For practical purposes copper wire is the best conductor, as it is comparatively cheap and has a low resistance. Iron and German silver have a higher resistance. Besides the *nature* of a substance entering into its resistance to an electric current, the resistance of a conductor is governed by its size. It is in inverse proportion to its cross-section. Just as a large water-pipe offers less resistance to the stream of water passing through it than a small pipe, so a large wire has a lower resistance than a small one. The standard unit of electric resistance (R) is the *ohm*, which is the resistance offered by a column of mercury at the freezing-point 106 cm. long and 1 sq. mm. in cross-section. It is approximately the resistance of a piece of copper wire 250 feet long and $\frac{1}{20}$ inch in diameter. Distilled water is a very poor conductor, while ordinary water, containing the usual mineral matter, is a good conductor. Adding ordinary salt or any other saline substance, or a base or an acid, increases the conducting power of water. For this reason it is best to wet in salt water the sponges or other electrodes used in giving treatment. The tissues of the body offer a very high resistance to

the current, particularly the skin, which gives a resistance of 5000 to 10,000 ohms.

The current (C) is the resultant of the two forces just discussed—viz.: the electromotive force and the resistance. It is the volume of current or flow, and in any given circuit is equal to the electromotive force divided by the resistance. This is Ohm's law. Expressed in algebraic terms, $C = E/R$. The unit of current strength is the ampere. An ampere is the current strength produced by one volt of electromotive force acting through one ohm of resistance. Practically stated, Ohm's law is this: The current strength in amperes is equal to the electromotive force in volts divided by the resistance in ohms. If in two circuits the electromotive force is equal, but in the second the resistance is double that in the first, then the current in the second will be one-half that in the first. Likewise, if in two circuits the resistance is the same, but the electromotive force in the second is three times that in the first, then the current in the second will also be three times that in the first.

Problems.—(1) A freshly prepared battery of 36 Leclanché cells furnishes an electromotive force of 54 volts. In treating a part of the body offering a resistance of 9000 ohms, what will be the current strength? Solution: $X \text{ (amperes)} = \frac{54}{9000} = .006$ amperes, or 6 milliamperes. (In these problems the internal resistance of the battery and its parts is disregarded.)

(2) A battery furnishing 48 volts is used in treating a part of the body offering a resistance of 6000 ohms; what is the current strength? Solution: $X = \frac{48}{6000} =$ .008 amperes, or 8 milliamperes.

(3) In using a battery having an electromotive force of 72 volts the meter registers 10 milliamperes; what is the resistance? Solution: If C = E / R, then E = CR and R = E / C. X (ohms) $= \frac{73}{.010} = 7200$ ohms.

(4) What is the electromotive force of a battery which in overcoming a resistance of 10,000 ohms shows a

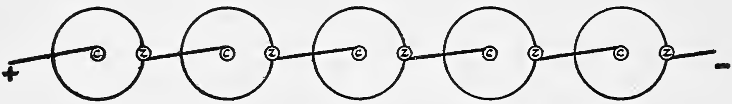

Fig. 10.—Cells arranged in series.

current strength of $4\frac{1}{2}$ milliamperes? Solution: E = CR. X (volts) $= .0045 \times 10{,}000 = 45$ volts.

Arrangement of Voltaic Cells.—One cell does not furnish sufficient electromotive force for practical use. For medical purposes a high resistance must be overcome, and from 24 to 36 cells are required. These should be arranged in *series*—*i. e.*, the carbon of one attached to the zinc of the next, and so on. The accompanying drawing shows such an arrangement (Fig. 10). The electromotive force of cells arranged in this way is equal to the sum of the voltages of the individual cells,

while the quantity of electricity generated is the same as that of a single cell.

Where a cautery is to be heated the arrangement must be entirely different. For this purpose the cells are arranged in *parallel* or *multiple arc.* To do this the like elements are all connected together. Such an arrangement is shown in Fig. 11. The voltage is that of

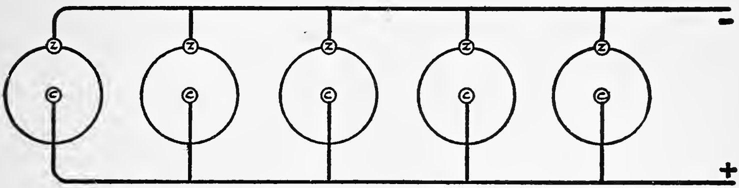

Fig. 11.—Cells arranged in parallel.

a single cell, while the amperage is equal to the sum of the amperes furnished by the individual cells; in other words, the arrangement produces results like a single large cell—*i. e.*, a cell with very large elements.

QUESTIONS FOR REVIEW

1. Name the essential parts of a galvanic cell.
2. Explain positive and negative elements.
3. Define polarization and give methods of preventing.
4. State Ohm's law.
5. Define volt, ohm, ampere.
6. Diagram arrangement of cells in series and in parallel. What result does each secure as to the current produced?

CHAPTER III

GALVANIC ELECTRICITY—THE BATTERY

In order to apply galvanic electricity for therapeutic purposes a number of different appliances and attachments are necessary to control the strength of the current and regulate the polarity conveniently. The

Fig. 12.—MacLagan rheostat.

following are the parts needed—a rheostat, a milliamperemeter, a rheotome, a pole-changer, and an off-and-on switch.

The rheostat (Fig. 12) is an instrument for regulating the current strength by varying the resistance interposed in the circuit. At the present time the wire

rheostat is used almost exclusively. The graphite rheostat has almost entirely gone out of use, largely because it wears out so quickly and often wears unevenly. The wire rheostat consists of a coil of fine resistance wire so arranged that a swinging arm throws into the circuit few or many of these coils (Fig. 13), and so decreases or

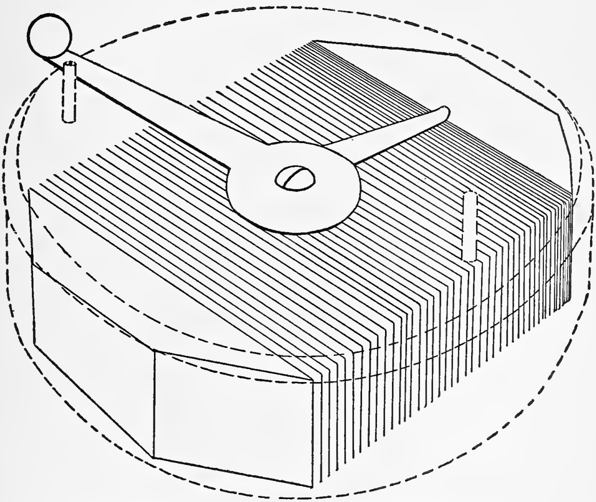

Fig. 13.—Rheostat open to show construction.

increases the resistance, the current strength in that part of the circuit varying inversely as the resistance.

In connecting up the rheostat it may be arranged in series or in shunt. Figure 14 shows the rheostat in series. The current must be turned on with the rheostat arm set for the greatest resistance. It is then gradually turned until the desired current strength is secured.

With the rheostat in series all the current passes through both the rheostat and the patient. Figure 15 shows the rheostat connected in shunt. Connected in this way there are two paths which the electricity from the battery may take—one through the rheostat, the other through the patient. The current strength in the two

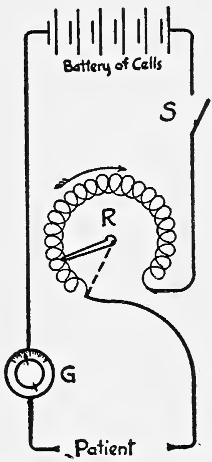

Fig. 14.—Diagram of rheostat in series.

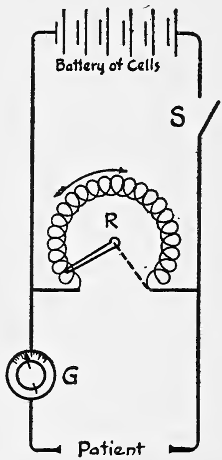

Fig. 15.—Diagram of rheostat in shunt.

shunts will be inversely proportionate to their relative resistances, *i. e.*, if the resistance in the rheostat is low the greater current passes that way and the patient will get but little current; and vice versâ, when the arm of the rheostat is turned so as to increase the resistance in the rheostat shunt the larger volume of the current is deflected into the patient's shunt. While the rheostat

connected in shunt is somewhat extravagant of current, it is more satisfactory, as the current can be turned on the patient at practically nothing and the increase be made very gradually. The rheostat in series is economical of current, but a slight shock occurs when the switch is turned on, as the entire electromotive force must pass through one channel.

The second necessity is a meter to register the volume of current used. Without the meter there can be no

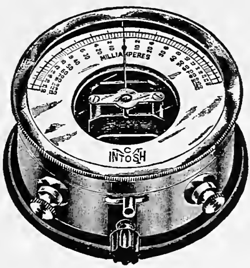

Fig. 16.—McIntosh milliamperemeter.

accuracy of dosage. The patient's sensation is no guide whatever, as some persons are very sensitive to electricity, while others take very strong currents without the slightest sensation being appreciated. For all-round use the meter (Fig. 16) should be provided with a shunt and two scale readings—one (usually in red) for delicate work, the other (usually in black) for larger currents. The shunts for these are controlled by a plug on the side of the instrument. The mechanism of the meter is based on the principle of the galvanometer.

The rheotome is an instrument for making and breaking the current automatically. Figure 17 shows a clock rheotome, in which the make and break is controlled by three springs which make contact with the teeth of three wheels. Each wheel has a different number of teeth. By means of a selector switch on the outside of the instrument the current is taken off any one of these wheels by its respective spring. This allows of varying at will the rate of interruption. In

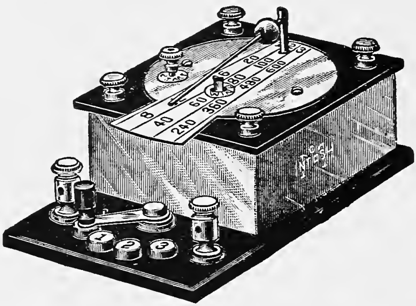

Fig. 17.—McIntosh graduated automatic rheotome.

order to give a still greater range of interruption rate the pendulum escapement is fitted with a movable bob, so as to increase or decrease the rate at which the toothed wheels move. With this instrument the break follows the make almost instantly. To bring the make and break farther apart the teeth should not be pointed, but the shape of a truncated cone or a mercury cup metronome may be used.

The pole-changer is a mechanism for changing the

direction of the current through the patient. It is used to avoid the inconvenience of moving the electrodes. The principle is well shown in Fig. 18. The two outside contact buttons are wired in common. When the two movable arms are swung to the right the positive pole is on the right side, while when swung to the left the positive pole is on that side.

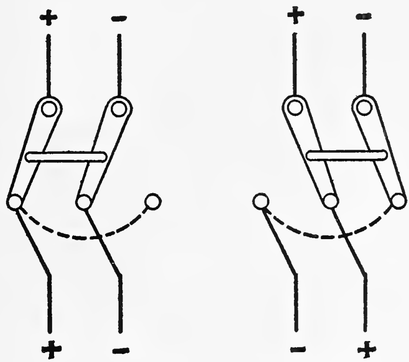

Fig. 18.—Diagram pole-changer.

These four instruments and the switch may be arranged on a wall plate or horizontal plate in any way desired. If a 110-volt direct current is used instead of cells, then a 16 c. p. light should be inserted in the main circuit in order to protect both the rheostat and the patient.

General Directions.—Before applying the current see that all parts of the battery are in working order and that a current is obtainable, as shown by the mil-

liamperemeter when the electrodes are attached and contacted with each other and the rheostat turned up. See that all connections are tight; that the rheophores (connecting cords) are firmly fastened to the binding posts and to the electrodes. See that the plug is placed for reading on the proper scale of the meter—red for delicate work, black for large currents. Next determine the polarity. This is best done by dropping the metal ends of the rheophores into a glass of water and turning on a moderate current.

Bubbles will soon collect on the negative pole, and if shaken will rise to the surface. A very few small bubbles will form on the positive pole, and if left long a gray cloud of oxid of nickel (in case of a nickeled tip) will diffuse into the water around this pole. These results are due to the electrolysis of the water, the hydrogen collecting at the negative pole and the oxygen at the positive. The gas at the negative pole is in greater quantity, since there is twice as much hydrogen (by volume) as oxygen in water (H_2O). The oxygen gas hardly shows bubbles at all, since it unites with the metal of the electrode, thus forming an oxid.

In case a phenolphthalein indicator is furnished with the battery, the negative pole will be indicated by a red color while the fluid around the positive pole is colorless. This is due to the fact that an alkaline reaction prevails at the negative pole, while an acid reaction is produced at the positive pole, and phenolphthalein is

red in an alkaline solution and colorless in an acid solution.

QUESTIONS FOR REVIEW

1. Explain fully the principle of the rheostat.
2. Diagram rheostat in series and in shunt and state advantages of each arrangement.
3. Tell how to test for polarity.

CHAPTER IV

ELECTROLYSIS AND CATAPHORESIS

If the poles of a galvanic battery are placed in a container of water and the current turned on, the water will soon show evidences of separation into elements—hydrogen and oxygen. If instead of ordinary tap water, water containing an acid, base, or salt be used, the decomposition becomes more vigorous and the compounds dissolved in the water are also decomposed. Certain elements or groups of elements in these compounds appear at the positive pole and certain other elements appear at the negative pole. This process is called "electrolysis," and the fluid which conducts the current, being decomposed by it, is called an "electrolyte." Electrolysis is the breaking up of compounds by the passage of the constant galvanic current.

For example, if a solution of ordinary salt (sodium chlorid, $NaCl$) be used, sodium appears at the negative pole in the form of sodium hydrate ($NaOH$), and gives rise there to an alkaline reaction, while chlorin appears at the positive pole as hydrochloric acid (HCl), giving rise to an acid reaction in the vicinity of this pole. Why is this? It is due to the fact that each particle bears

an electric charge. Opposite affinities having an attraction for each other, those particles which are electropositive—*i. e.*, bear a positive charge—will be attracted to the negative pole, and vice versâ, the electronegative particles will appear at the positive pole.

These electrified particles are called "ions." They may be atoms or atom groups (radicles). Those that appear at the positive pole are, therefore, called "anions," and those that appear at the negative pole, "cations." An anion is then an electronegative particle, and a cation an electropositive particle. The metals being electropositive will, therefore, be separated at the negative pole, and hence are cations. The non-metals being electronegative will be separated at the positive pole, and hence are anions.

While this law holds in general, yet the electric behavior of the various chemical elements goes to show that some are more strongly positive or negative than others, and that a given element may behave positively toward some elements and negatively toward others. The following arrangement of the elements in horseshoe shape shows their electric behavior toward each other. Each element behaves electronegatively toward those that follow it, but electropositively toward those that precede it.

The various elements, radicles, and compounds which make up the tissues of the body also manifest slight affinities.

Negative End.	Positive End.
Oxygen	Potassium
Sulphur	Sodium
Nitrogen	Lithium
Fluorin	Barium
Chlorin	Strontium
Bromin	Calcium
Iodin	Magnesium
Selenium	Aluminum
Phosphorus	Manganese
Arsenic	Zinc
Chromium	Iron
Vanadium	Nickel
Molybdenum	Lead
Tungsten	Tin
Boron	Bismuth
Carbon	Copper
Antimony	Silver
Tellurium	Mercury
Tantalum	Platinum
Silicon	Gold
Hydrogen	

Medical Electrolysis.—The principles of electrolysis are made use of in medical practice to bring about the removal or destruction of superfluous hairs, warts, moles, nevi, and other undesirable growths. Medical electrolysis is the destruction of tissue by means of the constant galvanic current. To obtain an exact idea of electrolytic effects secure a thick piece of lean beef. Insert into this two pieces of large copper wire attached as electrodes to a galvanic battery. Turn on the current to 30 or 40 milliamperes. It will soon be observed that a gas is forming around the negative electrode. After a time this forms a white foam, which collects around the wire where it enters the beef. In the course of a few

minutes a dark greenish discoloration will be observed in the meat around the positive electrode.

By this time, if traction is exerted on the electrodes, it will be found that the negative is loose, while the positive adheres firmly to the meat. What are the causes of these changes? The gas which forms around the negative pole is, of course, hydrogen produced from the water of the tissues. The softening of the meat, and the loosening of the electrode, are due to the collection around the negative electrode of alkaline substances, such as sodium and potassium hydrate. Alkalies soften and liquefy organic matter.

The adhering of the positive electrode is due to the formation around this pole of acid substances, such as hydrochloric and sulphur acids, which are produced from the chlorids and sulphur of the meat. These harden and dehydrate the tissues, hence the result. The dirty greenish discoloration around this pole is produced by the formation of copper oxychlorid and its diffusion into the tissues.

In the removal of superfluous hairs the skin should first be washed with a deodorized tincture of green soap and then with alcohol. The needle should also be dipped in alcohol, and the hands of the operator thoroughly washed with green soap. These precautions are not absolutely necessary in the majority of cases, but they will save an occasional infection. Attach to the negative pole a bulbous pointed platinum electrode and have

the patient hold a small hand sponge. Each hair to be removed is grasped lightly with a pair of epilating forceps held in the left hand. The needle is now pushed very gently into the follicle, alongside of the hair shaft down to the root. About 1 milliampere of current is turned on, and in a few moments the hair loosens and is removed without traction. The platinum electrode is used in order to avoid any possible staining of the tissues which might occur from iron oxid in case a steel needle were employed.

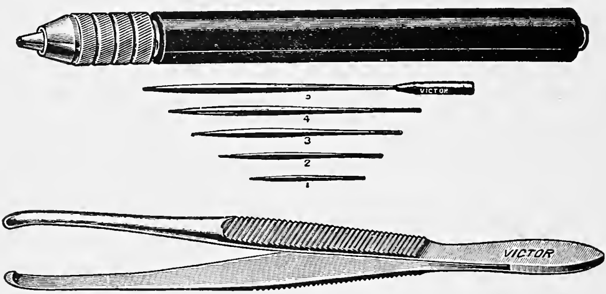

Fig. 19.—Electrolysis set.

To remove warts and moles a larger platinum needle or a gold needle should be used. It should have a sharp point, so as to be easily and painlessly inserted (Fig. 19). After thorough cleansing of the skin and needle, insert the latter through the base parallel to the skin surface. Hold the needle so as to guard against any other part touching the skin. Slowly turn on from 2 to 6 or 8 milliamperes according to the size of the growth. Con-

tinue the current until the tissue softens slightly and blanches immediately over the needle. This means that the blood-supply has been shut off and the tissue killed.

Turn down the rheostat, remove the needle, and reinsert parallel to and close by the first insertion or at right angles to it. This is repeated one or several times, according to the size of the wart or mole. It is well to use a weaker current for a longer time than to destroy the tissue around the growth by too strong a current. The devitalized area will show dark or black by the time the treatment is ended. Press gently several times with a piece of absorbent cotton dipped in alcohol. This helps prevent any possible sepsis and aids in drying the tissue. The spot treated should be allowed to dry, and should not be rubbed or moistened for two or three days. Do not cover with court plaster or collodion, as this is of no advantage and may encourage infection. The destroyed tissue will dry down and come off of itself in the course of time. A soft pliable scar is left which becomes less and less apparent with age.

For intra-uterine electrolysis prepare an electrode made of a number 10 or 12 copper wire, 8 or 9 inches in length, and guarded to within 2½ or 3½ inches of the tip by a soft-rubber catheter. It is designed that the exposed portion come in contact with the diseased endometrium only. The cervical canal, unless also diseased, should be protected from the action of the current by the rubber of the catheter. The patient should be

prepared by antiseptic douches and the intra-uterine electrode sterilized by boiling. Place a very large sponge or clay electrode over the lower abdomen. Attach this to the negative pole. The copper electrode is now inserted into the uterus (best by speculum under plain sight) and attached to the positive pole.

The rheostat arm is turned slowly until the milliamperemeter registers 25 to 40 milliamperes. Continue the current for eight to fifteen minutes. The electrode will be found to adhere quite firmly to the uterine tissue. Turn down the current, reverse the polarity, turn up again long enough to loosen the copper electrode. The current is then turned off, and the electrodes disconnected and removed.

Intra-uterine electrolysis is applicable in cases of glandular hypertrophies and small submucous fibroids in which there are menorrhagia or metrorrhagia which does not yield to curettage. The copper oxychlorid which is carried into the tissues sets up destructive (retrograde and atrophic) changes, which cause the atrophy and disappearance of the abnormal tissue. Cupric electrolysis should be used only in well-selected cases. It is not applicable in cases of mural or subserous fibroids or even of large submucous fibroids.

The use of the positive pole contracts the blood-vessels, thus assisting in the control of excessive or protracted flow and aiding in the starvation of the hypertrophic tissue. In treating vascular nevi it may also be

necessary to use the positive pole in order to guard against hemorrhage. In this case it is very necessary to use a gold or platinum needle, so as to avoid staining of the skin by an oxid.

Cataphoresis is the introduction of medicaments through the unbroken skin by means of the galvanic current. It is based upon electrolysis and ion transmission. It must not be supposed that medicaments or chemical elements placed under the positive pole are driven into the tissues in the direction of the current. Some elements travel in one direction, some in another. By the force of electrolytic action a medicine is broken up into its elements, the electronegative particles traveling toward the positive and the electropositive toward the negative pole. Which pole must be placed over the medicament will depend upon whether that part of the medicine desired in the tissues is electropositive or electronegative. There are very few medicines that it is desirable to introduce into the body in this way, and in the majority of cases other ways are quicker, less bother, and just as good or better in results. In fact, cataphoresis is an almost out-of-date method at the present time.

But suppose it is desirable to treat a goiter by iodin. A solution of potassium iodid is put on the negative pole, and, since the iodin is an anion, it will travel through the tissues toward the positive pole. All other electronegative substances (anions), such as bromin,

chlorin, etc., must be placed in the same way if it is desired to introduce them into the tissues through the skin. By reference to the table in the fore part of this chapter it will be seen the non-metals are all anions. They are the acid-forming substances. The metals and bases are all cations—*i. e.*, electropositive.

Suppose it is desired to introduce an alkaloid, such as cocain, into the skin for purposes of local anesthesia. This can be done by applying a solution of cocain hydrochlorid on the positive pole. Since the cocain is united with an acid and all alkaloids are basic in nature,

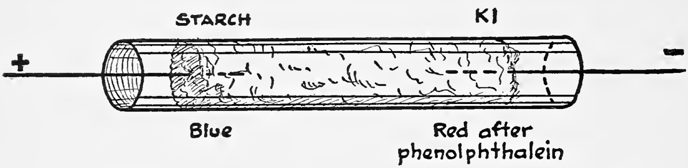

Fig. 20.—Ion transmission.

the cocain will be repelled by the positive pole and will travel into the tissues toward the negative pole. The result is the anesthesia of the skin into which the cocain has been carried. The acid radicle will remain on the positive pole—*i. e.*, be carried into the positive electrode if this is of sponge, cotton, or the like.

To demonstrate the ionic dissociation and the actual transfer of elements, fill a 5-inch glass tube loosely with wet absorbent cotton, placing in one end a plug of cotton dipped in potassium iodid solution, and in the other a plug of cotton dipped in starch solution (Fig. 20).

Now insert the negative pole into the cotton wet in potassium iodid and the positive pole into the cotton wet with starch solution. Turn on a strong current, say 50 or 60 ma., for about ten minutes. Near the expiration of this time the cotton wet in starch solution will turn blue, showing that the potassium iodid has been broken up into potassium and iodin, the latter having traveled to the positive pole, coloring the starch blue. To show that the potassium is still at the negative pole, and has been freed from the iodin, drop on the cotton at this end of the tube a drop of phenophthalein solution. A red color will immediately appear, due to the potassium hydrate, an alkali, which has formed at this pole.

In treating simple cystic goiter by cataphoresis, saturate a pad of cotton or a sponge electrode with a strong solution of potassium iodid and attach to the negative pole. Place the positive pole on the other side of the goiter or at the back of the neck. Use 15 to 20 ma. for five to eight minutes. This treatment must not be used in hyperthyroidism and may do harm in other cases.

QUESTIONS FOR REVIEW

1. Define medical electrolysis, cataphoresis.
2. What is an ion? Name two anions, two cations.
3. Why is the negative pole used for the electrolysis of moles?
4. What causes the positive pole to adhere in the tissues?
5. Which electrode is used for iodin cataphoresis? Why? For cocain cataphoresis? Why?

CHAPTER V

ELECTROTONUS

The explanation of the effects of the constant galvanic current upon the sensory and neuromuscular mechanisms is to be found in the phenomenon of electrotonus. If the positive and negative electrodes of a galvanic battery are applied along the course of a motor nerve, it will be observed that a stimulus applied in the region of the cathode evokes a greater contraction than otherwise, and that a stimulus of the same strength applied in the region of the anode calls forth a contraction of less magnitude than otherwise. The exciting stimulus may be either mechanical or electric (such as the shock of faradic electricity).

The passage of the constant galvanic current has produced around the cathode an area of increased irritability of the nerve, while in the area of the anode there is decreased irritability of the nerve. The same holds true for the sensory nerves—*i. e.*, they are less irritable in the region of the anode and more irritable in the region of the cathode (Fig. 21). These changes in the irritability of the nerve are known as electrotonus.

Electrotonus is the change in the irritability of the nerve produced by the passage of the constant galvanic current. The state of increased irritability which is present about the cathode is called "catelectrotonus," and the state of decreased irritability about the anode, "anelectrotonus."

The production of these phenomena is of considerable practical importance in the treatment of disturbances of nerve function. For example, in a case of facial neuralgia

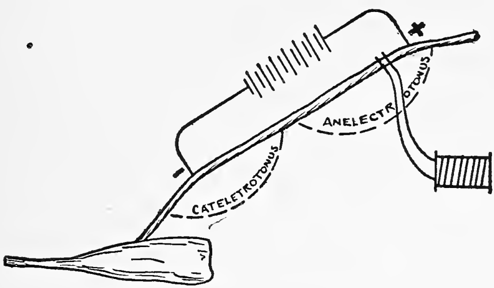

Fig. 21.—Electrotonus.

the pain may be lessened by the production of a state of anelectrotonus over the terminals of the trigeminal nerve. Hence, it is directed to apply the positive electrode over the painful area and the negative to the back of the neck or other indifferent part. This decreases the irritability of the nerve terminals and so lessens the severity of the pain.

In a case of marked nerve atrophy and consequent muscular paralysis, such as occurs in alcoholic neuritis,

it may be difficult to secure a contraction with the faradic or sinusoidal currents alone. To insure better results one of these may be combined with the galvanic current, either through two sets of electrodes or by means of one common set. In the case of a slowly interrupted faradic current to be combined with the galvanic, it should be so arranged that the induced current of the break is a descending current and the cathode of the galvanic current is nearest the muscle. Thus, one current reinforces the other, and the stimulus of faradism evokes a contraction where otherwise it would not, since it is applied in the region of the cathode where the nerve is in a state of increased irritability.

In this connection, although perhaps not coming strictly under the subject of electrotonus, we may discuss the effects of the interrupted galvanic current. No muscular contraction is produced by the galvanic current unless it is interrupted or suddenly increased or decreased in strength. The amplitude of contraction varies with the pole used and with the make and break of the current. With a current of 3 ma. the greatest contraction appears when the cathode is over the motor point and at the time of the make—*i. e.*, the closing of the current (C C C). With the anode over the motor point the contraction of the make (A C C) is less than with the cathode over the motor point, and the contraction at the break (A O C) still less. With this strength of current usually no contraction

occurs with the cathode at the time of the break, but with a current strength of 15 ma. a contraction appears (C O C). The amplitude of these different contractions is represented by the following formula, which is considered to represent the average or normal condition:

$$CCC > ACC > AOC > COC$$

Some nerves may give a slight variation from this formula. Variations due to current strength are best stated by Pflüger's laws: Weak currents give only a closure contraction; medium currents give opening and closure contractions; very strong currents in the direction of nerve conduction give only closure contractions; and in the reverse direction only opening contractions.

We are now in a position to sum up the effects of galvanic electricity. The general effects not already mentioned are chiefly tonic effects upon nutrition, circulation, and metabolism similar to those produced by hydrotherapy, massage, sun baths, etc. These effects, are, however, not so pronounced and are less in degree, and, hence, less important than the tonic effects of the other agents mentioned.

The nutritional effect of galvanism upon the nerves is greater than on the other tissues, as it supplies the place of the normal nerve impulses.

The local polar effects of galvanism may be summed up by the following table:

POLAR EFFECTS

	Anode (+)	*Cathode* (—)
1.	Liberates oxygen.	Liberates hydrogen.
2.	Produces an acid reaction.	Produces an alkaline reaction.
3.	Acid caustic.	Alkaline caustic.
4.	Dehydrates and hardens tissue.	Liquefies, softens, and disintegrates tissue.
5.	Scar produced is hard and unyielding.	Scar is soft and pliable.
6.	Vasoconstrictor.	Vasodilator.
7.	Stops bleeding.	Increases bleeding.
8.	Sedative.	Irritant.

QUESTIONS FOR REVIEW

1. Define electrotonus, anelectrotonus, catelectrotonus.
2. Explain the principles of the galvanic treatment of facial neuralgia.
3. With an interrupted galvanic current, where and when is the greatest muscular contraction produced?
4. Reproduce the table of polar effects.

CHAPTER VI

FARADIC ELECTRICITY

Electromagnetic Induction.—Magnetism and electricity are very closely related. By proper apparatus, magnetic force may be converted into electric force, or vice versâ, electric into magnetic. This is owing to the presence of lines of force surrounding the magnet (Fig. 22), and similar lines of force (a magnetic field)

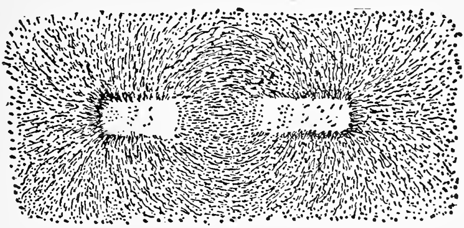

Fig. 22.—Magnetic phantom of bar magnet.

surrounding a wire through which a current of electricity is passing (Figs. 23, 24). A bar of soft iron or a bundle of soft iron wires, if made the axis of a coil or helix of wire through which an electric current is passing, becomes a magnet (Fig. 25).

The polarity of the magnet is governed by the direction of the current. The law is well illustrated in

Fig. 26, the diagrams of which represent the end of the magnet toward the observer. If the electric current in the helix passes in the direction of the hands of a

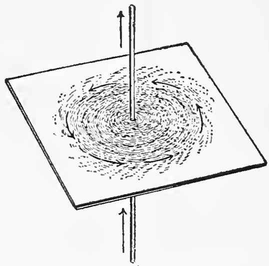

Fig. 23.—Magnetic field of straight wire.

clock (dextrorsal), the end of the bar nearest the observer will be the south pole. If the current passes in the opposite direction to the hands of a clock (sinistror-

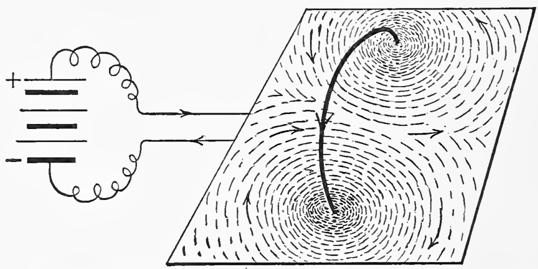

Fig. 24.—Magnetic field of coiled wire (helix). (Gage, "Principles of Physics.")

sal), the end of the bar nearest the observer will be the north pole. In either case the arrows on the letters *S* and *N* indicate the direction of the current.

Figure 27 illustrates an even simpler rule for determining the polarity of an electromagnet. Let the right hand grasp the helix, so that the fingers point in the direction in which the current is going, and the thumb will be on the side of the north pole.

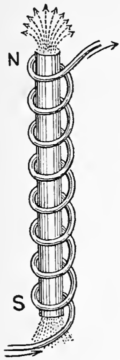

Fig. 25.—Production of electromagnet.

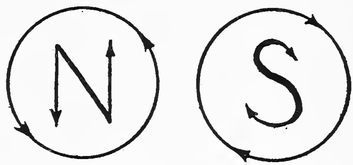

Fig. 26.—Diagram of polarity rule in case of electromagnet.

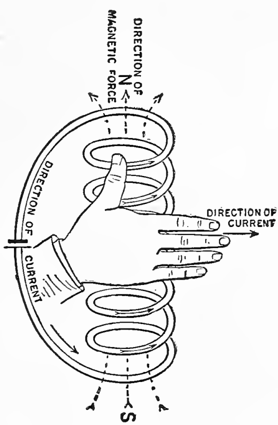

Fig. 27.—"Rule of thumb No. 2." (Gage, "Principles of Physics.")

The bar retains its magnetism as long as the electric current is passing through the wire. This fact, together

with the laws governing the production of electric currents by magnets and by other or primary electric currents, is well and briefly stated by Tousey:[1]

"From the time the current is turned on until it is turned off the soft-iron rod remains an equally strong magnet with its polarity unchanged. This is the case when the electric current is uniform as to direction and strength. Any variation in either the polarity or strength of the electric current will produce a corresponding change in the polarity or strength of the magnet. It is important to remember that the effect of an electric current upon an iron core is continuous as long as the current lasts. This is not the case with two other forms of induction which we shall have to consider. First, a current of electricity induced in a coil by a magnet is only momentary, and occurs only when the magnet is carried toward or away from the coil. The electric current does not continue to flow while the magnet is at rest within the coil or anywhere else.

"The other case is that of electric currents induced in other wires by a current passing through a primary wire. The currents are induced only when the primary current is made or broken, or when its strength is increased or diminished, or when it is brought near to or away from the secondary wire, and in either case it is of momentary duration. No electric induction takes

[1] Medical Electricity, Röntgen Rays, and Radium, *2d Ed.*, p. 103 (W. B. Saunders Company).

place during the uniform flow of an electric current, but that same uniform flow will maintain magnetic induction in an iron core."

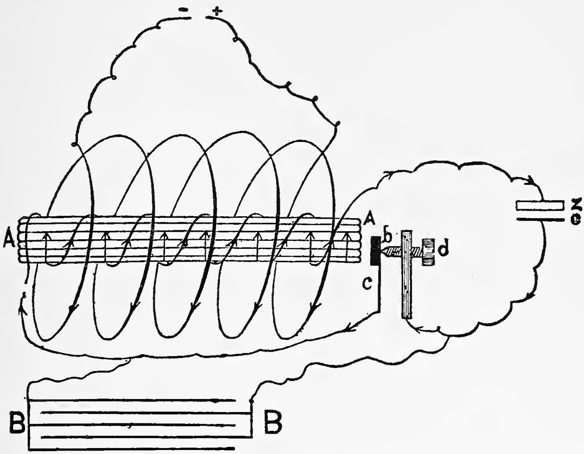

Fig. 28.—Induction coil: A, Core of iron rods; B, condenser, to get rid of the *extra* current which runs back on the *induced* current; *b*, iron armature; *c*, spring of interrupter; *d*, set screw carrying platinum point; *z*, *c*, battery; — and + are the secondary poles.

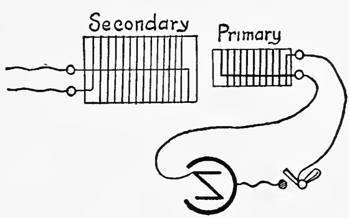

Fig. 29.—Diagram of faradic battery. Induction coil for single shocks.

The Faradic Battery.—These laws of electric induction are made use of in the production of faradic electricity. The faradic battery (Figs. 28, 29) consists of

a primary and a secondary coil of wire, a vibrator or interruptor, a soft-iron core, and the dry or wet cells (one or two are usually sufficient) which supply the current to the primary coil. The primary coil is wound about the soft-iron core, which usually consists of a bundle of iron wires. The secondary coil contains much more wire, and is wound outside the primary. The wires from the battery of galvanic cells pass to the ends of the wire in the primary coil. To provide for induction the primary current must be an interrupted current. This is accomplished by inserting in the circuit an interrupting mechanism. This usually consists of a spring attached to the base of the machine and bearing a piece of soft iron on its free end. The spring is so placed that the soft-iron head is near one end of the soft-iron core. The wire from the near end of the primary coil is attached to the base of this spring. The circuit is completed through a regulating screw, which is adjusted to make contact with the spring, and to which the wire from one pole of the battery is attached.

As soon as the circuit is completed by the contact of the regulating screw with the vibrator spring, the soft-iron core becomes a magnet by electromagnetic induction from the current in the primary coil. The core, now a magnet, attracts the iron head of the vibrator, and, drawing it away from the regulating screw, the circuit is broken. As soon as the current ceases to pass in the primary coil the soft-iron core looses its magnetism

and the vibrator flies back, again making contact with the screw and completing the circuit. The soft-iron core is again magnetized, and the whole procedure is repeated, rapidly making and breaking the current in the primary coil. It is not necessary that the primary coil possess an iron core. An electromagnet may be inserted in the primary circuit elsewhere, and the current be made and broken by it, or a mechanical interrupter, such as the metronome, may be used.

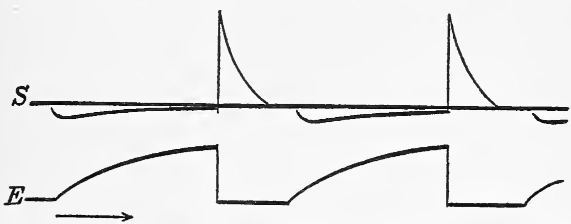

Fig. 30.—Curves of primary and secondary faradic currents: *S*, Secondary current; *E*, exciting current.

At each make of the current in the primary coil a current is induced in the secondary coil opposite in direction and momentary in duration. At each break of the current in the primary coil there is induced in the secondary a current of very brief duration, passing in the same direction as that in the primary before the current was broken. The curves of these currents are shown in Fig. 30.

The curve above the base line indicates a current in one direction, and that below the base line a current in the opposite direction. The primary or actuating

current is similar to an interrupted galvanic current (Fig. 31), except that it is modified by self-induction and so rises less abruptly. This curve is shown in the lower tracing (Fig. 30, *E*). The upper one represents the current in the secondary coil. That below the base line is the current induced at the make. It will be noted that it is not a strong current and that it dies out gradually. The curve above the base line is the current of the break. It is a strong current, rises abruptly, and dies out quickly. When the primary coil is deprived of its iron core there is less self-induction, the current

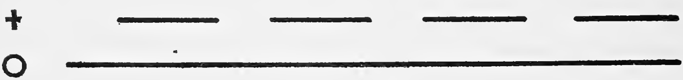

Fig. 31.—Diagram of interrupted galvanic current.

in the primary rises more rapidly, and in the secondary circuit the currents of the make and break are more nearly alike in magnitude and duration.

The following are the laws of induced currents:

(1) At the instant when the primary current begins to flow, or to increase in intensity, or the primary coil approaches the secondary, an induced current, inverse and momentary, is developed in the secondary coil or circuit.

(2) At the moment this current ceases in the primary circuit, or when its intensity diminishes, or when the

primary coil recedes, an induced current begins in the secondary coil or circuit direct and momentary.

In principle the faradic battery is a step-up transformer. The secondary coil is made of finer wire and many times longer than the primary. The pressure or generating force in the secondary circuit is increased by each additional turn of the wire. It thus exposes to the lines of magnetic force about the primary coil and its iron core additional wire upon which this inducting force may act. If there are twice as many turns of wire in the secondary coil as in the primary, the voltage of the secondary current will be twice that of the primary current. But as the voltage in the secondary increases, the amperage decreases, and in corresponding proportion—*i. e.*, with twice the voltage there will be one-half the amperage of the primary circuit. A step-up transformer produces a current of higher voltage, but lower amperage. Conversely, a step-down transformer produces a current of lower voltage and higher amperage.

It is necessary that a faradic battery have some device for regulating the strength of the secondary current so as to suit it to the sensitiveness of the patient. Small batteries usually have only the shield about the iron core. This is a metal cylinder which may be drawn out or pushed in (Fig. 32). It is designed to interfere with the magnetic field of the iron core, hence the current in the secondary will be weaker, or at least give less pronounced sensory effects when the shield entirely

covers the core. As it is drawn out the secondary current becomes stronger by the force of a stronger magnetic field about the iron core.

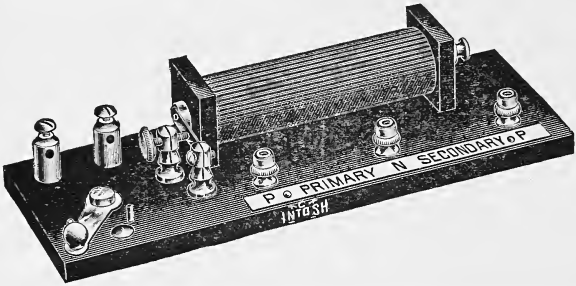

Fig. 32.—McIntosh small faradic battery with metal cylinder controller.

Larger faradic batteries are usually made with a small wire rheostat in the primary circuit. Besides this, they

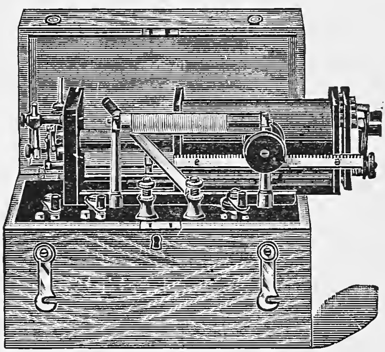

Fig. 33.—Compound faradic coil.

may be provided with several secondary coils wound on the same hollow spool (Fig. 33). The finer the wire and the longer the winding, the greater the voltage

produced. The different windings may be used independently of each other as desired. This is accomplished by coil-selecting switches. Besides this, the secondary coils are usually movable so as to be drawn away from the primary to any extent desired. These different means for varying the strength of the current, together with regulating the vibrating mechanism (mentioned later), allow of quite perfect control, so that the battery may be used for a variety of effects.

Physiologic Effects and Therapeutic Uses.—It is the interrupted and alternating character of the secondary current, together with its relatively high voltage, that is the basis of the sensory effects it produces. The primary current of the faradic battery is a modified interrupted galvanic current of very low voltage. When derived from a small battery it produces but slight sensory or muscular effects. The secondary current is an interrupted and alternating current of unequal phases with high voltage and low amperage. It produces marked sensory and muscular effects. The contraction at the break is greater than that at the make. It has no true polarity and no electrolytic effects, but in a large battery the contraction produced by one electrode is greater than that produced by the other electrode.

A well-constructed faradic battery should have at least two interruptors—a rapid and a slow. For general tonic and sedative effects the rapid interruptions serve

the purpose very well; but for neuromuscular massage and strengthening weak muscles—*i. e.*, for producing vigorous and intermittent contractions—the slow interruptions are best. With rapid interruptions a tetanus of the muscle is produced. With slow interruptions a clonic contraction results. There are four important uses of the secondary faradic current—viz.:

(1) In treating degeneration of nerves and muscles.

(2) As a general muscular tonic.

(3) As a general (tonic) sedative.

(4) For relief of paresthesias.

(1) **Degeneration of Nerves and Muscles.**—In infantile paralysis, peripheral neuritis (as of alcoholism), and in hemiplegia the nerve-fibers or their central cells undergo degeneration and the muscles atrophy as a consequence. Where a nerve trunk is severed by accident, as from a knife cut, the severed portion degenerates and the muscles supplied by it atrophy. In all these conditions a secondary faradic current is useful in exercising the muscle to prevent atrophy and in securing the maximum regeneration of nerve and muscle that may be possible in a given case. The electric current and the sensory shock supply the place of the normal nerve currents and stimuli, which no longer exist or are not strong enough to produce results.

(2) **As a General Muscular Tonic.**—Faradic electricity is useful in neurasthenics, chronic invalids, and others for general tonic purposes, just as we use hot

and cold applications, massage, and sunshine for the same purpose. This may be in the form of general faradization or by the faradic tub-bath. The current should be fairly mild, with rapid interruptions. Also in weak abdominal muscles, in atonic constipation, and in lateral spinal curvature the faradic current may be used as a neuromuscular massage to strengthen the weakened muscles. For this purpose the slow interruptions are best.

(3) **As a General Sedative.**—For this purpose the conditions treated and the methods used are the same as those first considered under item number two. The insomnia of neurasthenia and chronic invalids frequently yields to mild tonic measures, such as general faradization or the faradic tub-bath.

(4) **Paresthesias.**—In tingling, smarting, and other abnormal sensations a mild current of rapid faradic applied to the affected skin surface frequently gives gratifying results. In a few cases headache is relieved by the same means; the current should be applied through the hand of the operator.

QUESTIONS FOR REVIEW

1. Diagram a faradic battery.
2. Diagram the primary and secondary faradic currents and explain.
3. Give the laws of induced currents.
4. What is a step-up transformer?
5. In what ways may the strength of the secondary faradic current be varied?
6. What, in general, are the uses of the faradic current?

CHAPTER VII

SINUSOIDAL ELECTRICITY

THE sinusoidal current is produced by an alternating-current dynamo, consisting of a soft-iron core with helix, which revolves between the poles of a permanent magnet. It is constructed on the same plan as the magneto of a telephone system. The current produced is graphically shown in Fig. 34. It will be seen that

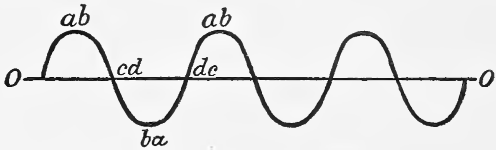

Fig. 34.—Sinusoidal current.

this is a continuous, alternating current of equal positive and negative phases, which increase and decrease gradually and not abruptly, as does the break current of a cored faradic coil.

A sinusoidal dynamo for medical purposes, with motor and rheostat, is shown in Fig. 35. It will be noted that the magnetic field is supplied by several horseshoe magnets fastened together. Between the poles—*i. e.*, within the magnetic field—of these mag-

nets is rotated a coil of wire wound upon a soft iron core. The diagram (Fig. 36) shows the essential parts of the dynamo. The inner side of the ends of the horseshoe magnets is so shaped as to constitute segments of the circle described by the soft-iron core, the ends of which are similarly shaped. When this soft-iron core stands crosswise between the poles of the permanent

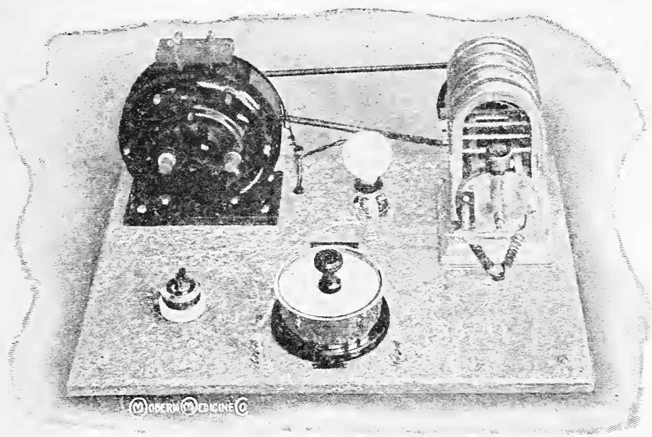

Fig. 35.—Sinusoidal apparatus.

magnets it becomes magnetized with a polarity corresponding to its position. Let the initial position be considered *ab*. As it revolves it gradually loses its magnetism until in position *cd* it ceases to be a magnet, since all parts of the soft-iron core are equidistant from the poles of the permanent magnet. Continuing its course it gradually regains its magnetism until, in position *ba*, the maximum is reached, but with polarity opposite

to that which it possessed in position *ab*. This magnetism is gradually lost as the core approaches position *dc*, and again gradually regained as it approaches its initial position *ab*.

From this explanation of the changes in the magnetism of the soft-iron core the manner in which the current is

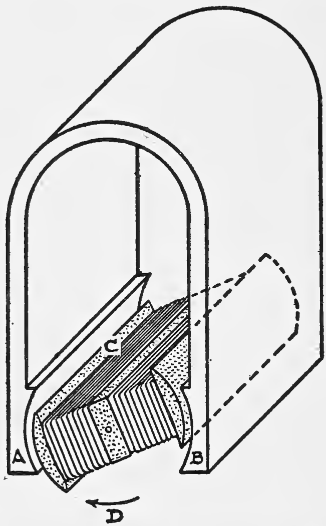

Fig. 36.—Diagram of sinusoidal dynamo.

produced in the coil of wire around it becomes perfectly apparent. It follows the laws of electromagnetic induction stated in Chapter VI. When the iron core is in position *ab*, a current is produced in the coil of wire in a certain direction, let us say, corresponding to the curve at point *ab* in Fig. 34. As it revolves the strength of the current gradually decreases until it is nil in posi-

tion *cd*. Continuing to position *ba* the current gradually increases to a maximum, but in the opposite direction, since the polarity of the core is reversed. As the position *dc* is approached, reached, and receded from, the current gradually decreases to nothing, and then gradually increases in the opposite direction until the maximum is again reached in position *ab*. Thus is produced an alternating but continuous current, the strength of which increases and decreases gradually.

The alternating character of the current provokes a vigorous and powerful muscular contraction. It is painless, or nearly so, because the maximum strength of the current in both directions is approached and receded from gradually. It is believed by physiologists that this more nearly resembles the normal motor nerve impulse than the stimulation produced by the sharp interruptions and alternations of the faradic current. Because of the painlessness of the muscular contractions produced a stronger current can be used than with faradic electricity. It is, therefore, of great usefulness in the treatment of muscular paralyses and in exercising weak, flabby muscles—*e. g.*, of the abdomen.

The electric motor which drives the sinusoidal dynamo should be so constructed that it may be run slowly or rapidly. As with faradic electricity, rapid sinusoidal (Fig. 37) produces a tetanus of the muscles, while the slow sinusoidal (Fig. 38) evokes a clonic contraction. A mild current of the former is useful for general tonic

and sedative purposes, the latter for deep and painless neuromuscular massage.

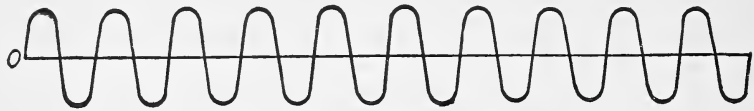

Fig. 37.—Sinusoidal current—rapid.

Fig. 38.—Sinusoidal current—slow.

Fig. 39.—Surging galvanic current—rapid.

Fig. 40.—Surging galvanic current—slow.

Fig. 41.—Surging sinusoidal current.

Fig. 42.—Sine curve current produced by rhythmic rheostat and pole-changer.

Besides the simplest true alternating sinusoidal current there are many modifications. The basis of all

sinusoidal currents is the gradual increase and decrease in the strength of the current. By special apparatus a unidirectional, undulatory, or surging galvanic current may be produced. The rapid and slow surging galvanic

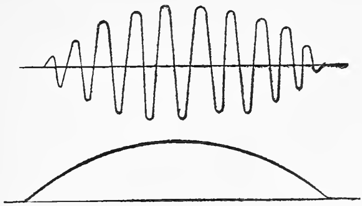

Fig. 43.—Sinusoidal current with rhythmic variation in strength. Muscular contraction similar to physiologic one. (Tousey.)

currents are shown in Figs. 39 and 40. An alternating current may be converted into a surging sinusoidal with rhythmic increase and decrease in strength (Fig. 41). A third current, resembling the sinusoidal, is

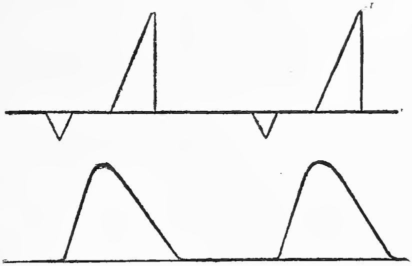

Fig. 44.—Isolated induction shocks producing abrupt muscular contractions. (Tousey.)

shown in Fig. 42. These are all useful for the same purpose, namely, the production of painless and vigorous muscular contractions. The contrast in the character

of the muscular contractions produced by the surging sinusoidal, the slow faradic, and the rapid faradic currents is shown in Figs. 43–45. From these diagrams the great advantage of the sinusoidal currents over the faradic current will be readily grasped. Besides

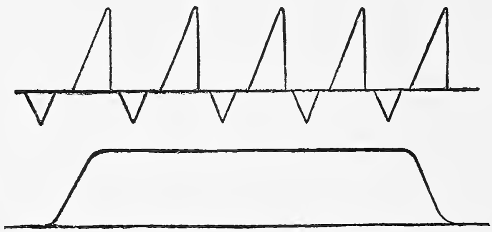

Fig. 45.—Rapid faradic current producing an abnormal muscular tetanus. (Tousey.)

this, the periods and strength of the current can be exactly regulated. They are not subject to the irregularities present in the action of even the best faradic coil.

QUESTIONS FOR REVIEW

1. Diagram the sinusoidal dynamo.
2. Diagram and explain the sinusoidal current.
3. What advantage has the sinusoidal current over the faradic?
4. What are the chief uses of sinusoidal electricity?

CHAPTER VIII

TECHNIC AND PRESCRIPTIONS

Electrodes.—These are of various sizes and materials, according to the use to which they are to be put. Sponge-covered electrodes are very serviceable, as they are soft and readily adaptable to any surface. They are easily cleaned and cheaply renewed with the new sea sponge when worn. The hand-size (Fig. 46) is suitable

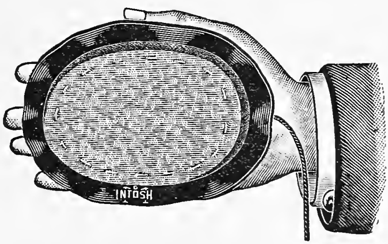

Fig. 46.—Sponge electrode—hand size.

for the stationary (stabile) electrode in giving mild currents of galvanic and faradic electricity, and is much used as the movable (labile) electrode for galvanic, faradic, sinusoidal, and combined currents. The smaller size with handle (Fig. 47) is much used as the labile electrode in administering faradic currents of any strength, also interrupted galvanic and sinusoidal cur-

rents, to produce muscular contractions in cases of paralysis. These same electrodes may be covered with a cotton felt instead of sponge. It is very necessary that the felt electrodes should be covered with gauze or

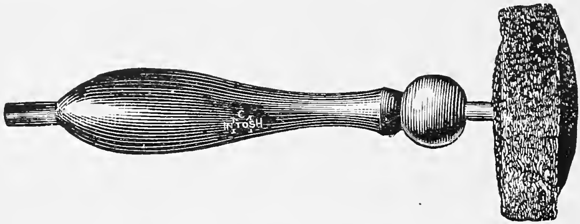

Fig. 47.—Spongio electrode—handle form.

cheese-cloth, as they are not easily washed, and would otherwise become so badly soiled as to require renewal. In the absence of anything better, metal electrodes may be covered with wet absorbent cotton fastened on with

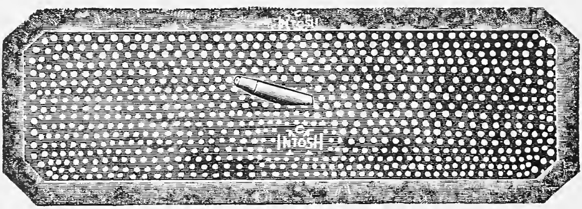

Fig. 48.—Spongio-covered electrode for spine.

cheese-cloth. Before using any electrode of sea sponge, cotton, or cotton felt it should be thoroughly moistened with salt water.

Larger stabile electrodes, for use on the spine, abdomen, etc. (Figs. 48, 49), are usually made of felt fast-

ened on a flexible base of fine mesh screen or perforated sheet metal. Cloth-covered electrodes of plain sheet metal (zinc or nickeled copper) are less desirable, as they do not perfectly conform to irregular surfaces, and so by closer contact over bony prominences may cause a burn. It is, therefore, the function of a stabile electrode to distribute evenly a strong current, so that by prolonged contact a burn will not result. To accom-

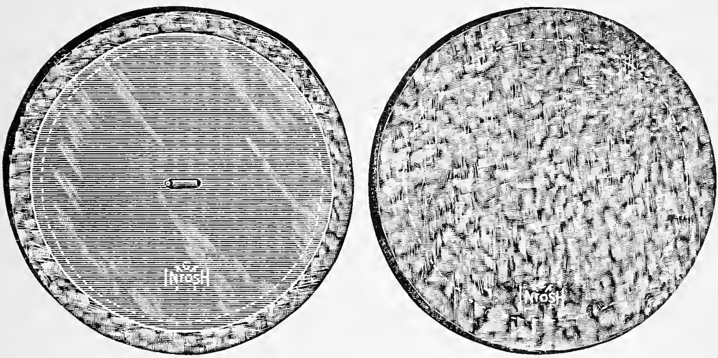

Fig. 49.—Hayes Spongio-covered electrode for abdomen.

plish this the stabile electrode must be large—much larger than the labile—and it must fit evenly over the entire surface and contact with uniform pressure at all points.

In giving large currents of galvanic electricity for intra-uterine electrolysis nothing is so satisfactory for the stabile electrode as white clay. This is made by mixing up in a shallow pan, lined with three or four layers of gauze or two of cheese-cloth (large pieces), a

stiff pad of clay and water about $\frac{3}{8}$ inch thick. On this place a piece of $\frac{1}{4}$-inch mesh galvanized wire screen, of the shape and slightly smaller than the size of the electrode desired. To this screen should have been previously soldered a screw connection for the rheophore. Now cover the screen with another layer of stiff clay, being sure that all edges and corners are doubly well covered and deeply concealed. The edges of the gauze or cheese-cloth are now brought up over the upper surface and sewed across so as to entirely cover the clay

Fig. 50.—Wristlet electrode.

and serve as a retainer for it. This electrode must be kept moist when not in use. On using it should be temporarily covered with a couple of extra layers of gauze, which are thrown away after using. The electrode should be easily flexible, and when used be pressed evenly on the surface to which it is applied. Its even contact makes a galvanic burn almost impossible. For administering 25 to 100 ma. it should be from 6 to 10 inches in diameter.

Where the operator's hand is to be used as the labile electrode the wrist should carry a wristlet electrode,

having on its inner side a small sponge (Fig. 50). In applying electric currents about the head and face this is often desirable.

Tubs for electric baths, especially galvanic and sinusoidal, must be insulated. The supply faucets should stand *over* the foot of the tub instead of coming *through* the foot of the tub. The outlet and overflow should dis-

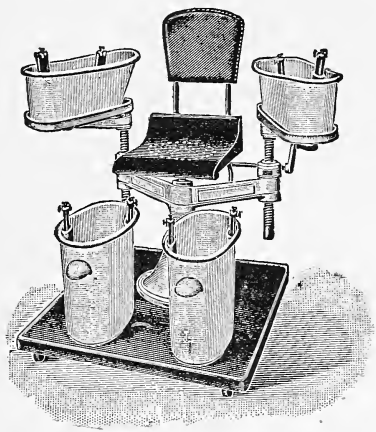

Fig. 51.—Schnee's four-cell bath. (Harris.)

charge into a gutter; never should they be directly connected with the plumbing. Instead of a full-length tub for the hydro-electric bath, Schnee's four-cell bath (Fig. 51) is very much used.

In applying faradic electricity to fleshy parts a roller electrode (Fig. 52) may be used instead of the sponge electrode with handle. Unless covered with chamois it should not be used in giving galvanism. For an intra-

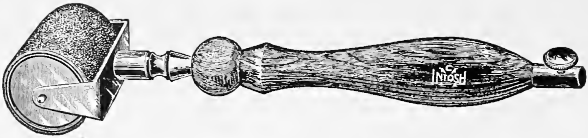

Fig. 52.—Massage roller electrode.

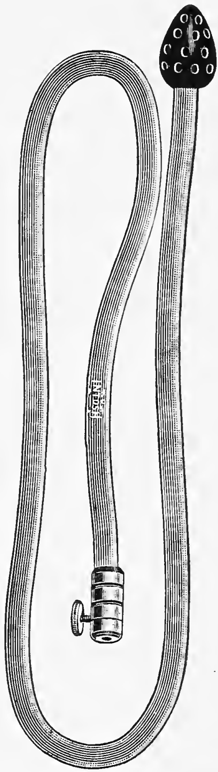

Fig. 53.—Intragastric electrode.

gastric electrode (Fig. 53) for applying faradic or sinusoidal currents a rubber-covered flexible cable is used,

having on its extremity a small olive-shaped hard-rubber piece with many perforations, through which the water in the stomach makes contact with the metal terminal of the wire cable. No metal can touch the stomach wall. The water which the patient drinks serves to complete the contact. The electrode is swallowed as a stomach-tube would be.

For use in the rectum an electrode should have a hard-rubber stem with exposed metal extremity (Fig. 54). Before using, this metal extremity should be covered with a tightly fitting chamois-skin finger. This is wet before inserting. For general use vaginal electrodes

Fig. 54.—Rectal electrode.

are prepared in the same way. Other electrodes for use in the urethra, nose, etc., we need not describe here, as they may be safely used only by the specialist. Electrodes for intra-uterine electrolysis, and for the removal of moles, warts, nevi, and superfluous hairs, have been described elsewhere. The former, of course, is to be used only by a physician.

General Rules of Technic.—The stabile electrode should always be of larger size than the labile. It should be so placed that contact will not be broken by any slight movement of the patient or the rheophore become

loosened. As a general rule, unless otherwise desirable or specially ordered, the stabile electrode should cover the spinal center of the nerves supplying the part to be treated. For the arm this will be the cervical and upper dorsal spine, and for the legs the lumbar and sacral spine. When the labile electrode is to be applied to the spine the stabile electrode may be placed on the abdomen. In these three positions the weight of the patient maintains firm contact with the electrode. As the electrode must be wet, it is well to place a towel between it and the patient's clothing or the bed linen.

For general galvanization and general faradization the patient sits upon, or lets his feet rest upon, the stabile, indifferent electrode—a large piece of metal covered with a wet flannel or thick cotton cloth.

The labile electrode should usually be much smaller than the stabile electrode. In giving galvanic currents see that the polarity is right before attaching the rheophore. This should be fastened firmly, as an accidental disconnection may be the occasion of a very disagreeable shock to the patient. See that all parts of the apparatus are in working order before beginning. Move the electrode over the surface with an even pressure and at a uniform rate. In administering any form of an electric current do not remove the electrode while the current is turned on. Avoid bony prominences. In administering treatment to produce muscular contractions, or in case of degenerated nerves,

seek out the motor points (see Figs. 55, 56) and pass the electrode over these rather than over other places. For sanitary reasons, it is best to cover the labile electrode with gauze or cheese-cloth and renew it for each patient. In treating the limbs, move the electrode in a direction parallel with the long axis of the limb. In treating the arm move the electrode from finger-tips to elbow back and forth in closely placed and parallel lines until the entire circumference has been covered once, twice, or more times, as needed for the individual case. Treat next the upper arm from elbow to shoulder, including the shoulder muscles. In treating the chest the movements should be parallel to the ribs. For the back the movements may vary considerably, being circular, transverse, or longitudinal, according to the parts or muscles to be affected. Always bear in mind that the motor points are to be given special attention.

For the legs the same general directions may be followed as with the arm, treating the backs of the thighs and buttocks after the back has been finished. For the back the movements should be up and down on either side of the spine over the erector spinæ muscles, but farther from the center line they should be parallel with the ribs.

Treatments should usually be of short duration, as fatigue of the muscles is undesirable. When the galvanic is combined with other currents the direction of the former should usually conform to the direction of the normal nerve impulse. For example, in applying the

galvanic and sinusoidal currents together the positive electrode should be placed over the spinal center of the nerves supplying the part to be treated. The nearer the electrically excited contraction conforms to the normal volitional contraction, the better the result produced. For this purpose the galvano-faradic current, modified by a rhythmic rheostat and pole-changer after the method of Tousey, is ideal. It produces trophic changes, as well as evoking a nearly normal muscular contraction. It is agreeable and exhilarating. It embodies the principle of the sinusoidal current. For the relief of neuralgic pain positive galvanism is used.

PRESCRIPTIONS

General Faradization.—The patient sits upon or lets his feet rest upon the large indifferent electrode. The other electrode is passed over the forehead, back of the neck, spine, chest, abdomen, and legs. This active electrode may be the sponge-covered handle electrode, the hand-sponge electrode, or the operator's hand. In the latter case the wrist electrode is attached to the operator's wrist. Rapid interruptions and the fine secondary winding should be used. The sitting should last about ten minutes. General faradization is useful in neurasthenia with muscular weakness and malnutrition, and as a general tonic and tonic sedative in chronic invalids.

Local Faradization.—The indifferent electrode is ap-

plied to the spine over the nerve-centers supplying the part to be treated, or over the nearest neutral point, such as the abdomen, buttocks, soles of the feet, or palms of the hands. The active electrode is passed back and forth over the affected part. Rapid interruptions and the fine secondary winding are used. The treatment lasts three to five minutes. It is useful in the atrophy of disuse, in paresthesias, some cases of neuralgia, anemic headache, and in local palsies where other currents are not available.

General Galvanization.—This is applied in the same way as general faradization; 2 to 5 ma. of current are used. The treatment is said to act as a stimulant to nutritional processes.

Central Galvanization.—This consists in the application of the positive pole to the nerve-centers. It is applied by placing a large stabile negative electrode over the epigastrium, while the small positive electrode is passed successively over the forehead and vertex, the sides of the neck, and down the entire length of the spine. The strength of the current varies from 5 to 10 ma., according to the part under treatment, being less for the head and neck and more for the spine as the distance from the head increases. The treatment lasts ten minutes. Central galvanization is useful for sedative purposes in hysteria, neurasthenia, insomnia, etc., in patients whose nutrition and muscular strength has not been affected by the disease.

Trigeminal Neuralgia.—After ruling out those cases due to pressure upon the nerve by tumors or exostoses, facial neuralgia may in many cases be much benefited by positive galvanization. The indifferent negative electrode should be of large size, and applied to the back of the neck or between the shoulder-blades. A clay pad or felt electrode is best. The positive electrode should also be stabile and large enough to cover the painful area, whether of one or all three branches of the fifth nerve. It must make even contact. The current should be turned on very gradually. From 3 to 12 ma. may be applied for fifteen to thirty minutes, or as long as one hour. Heavy galvanic currents for prolonged application should be administered only by a physician expert in electric applications. The treatment should be supplemented by other measures—thermic, light, ionic medication, or injection into the nerve trunk or the gasserian ganglion in severe intractable cases.

Sciatica.—In sciatic neuralgia the constant galvanic current may give relief. Apply it in the same way as for trigeminal neuralgia. Considerably stronger currents may be used, even 30 to 50 ma., for ten to twenty minutes. However, milder currents, 10 to 15 ma., are frequently successful. Both ascending and descending currents may be tried. In some cases counterirritation with the faradic brush electrode may be tried. Static and high-frequency applications are also useful, the latter especially so in many cases. Schnee's four-

cell galvanic bath is recommended for sciatic neuralgia, also for the lightning pains of locomotor ataxia and in articular rheumatism.

Poliomyelitis.—Infantile spinal paralysis following an acute poliomyelitis in a large majority of cases responds well and successfully to electric stimulation. Never begin treatment while acute symptoms are present, such as pain and tenderness. Those who have had large experience advise waiting eight to twelve weeks after the onset. Faradic electricity gives the best results, or it may be combined with a descending galvanic current. Apply the stabile electrode over the spinal center of the nerves supplying the paralyzed muscles. Move the labile sponge about over the motor points of the affected muscles. Where there are contractures in old cases avoid the spastic muscles. The treatment should be repeated daily. The faradic or sinusoidal tub-bath may be used. The treatment should be supplemented by hydrotherapy and massage.

Hemiplegia.—Electric stimulation may be begun in four or five weeks after the apoplexy. A descending galvanic current may be used, placing the anode over the cervical and upper dorsal spine and moving the cathode about over the paralyzed muscles. Local faradization is useful in preventing the atrophy of disuse.

It may be given for five to eight minutes daily. Passive joint movements, massage, and tonic and sedative

hydrotherapy are also useful in preventing atrophy and contractures.

Peripheral Neuritis.—In the chronic stage with reaction of degeneration, galvanofaradization may be used or the sinusoidal current. The interrupted galvanic current is also useful. Where there is both motor and sensory degeneration the faradic current with slow interruptions is especially indicated.

Insomnia.—Use central galvanization or the hydro-electric bath. In giving the galvanic bath fix the positive electrode under the pillow or near and between the shoulders. It should not touch the skin. The negative is placed at the foot of the tub; 50 to 100 ma. may be used. The precautions mentioned elsewhere must be carefully observed. Salt should not be added to the water, as the patient then gets but little of the current. Ten to twenty minutes is the proper duration of treatment. The current must not be turned on until the patient is in the bath, and must be turned off before he gets out. Warm tub-baths, with mild currents of rapid faradic or sinusoidal electricity, are to be most highly recommended for general use in the treatment of the insomnia of neurasthenia.

Headache.—Use central galvanization or apply positive galvanic current to head only, through the operator's hand; 3 to 5 ma. are used for five to twelve minutes. In some cases a mild current of rapid faradic is beneficial. It should be applied through the hand.

Scoliosis.—Use slow sinusoidal, surging sinusoidal, or an induction-coil current modified by a rhythmic rheostat. Applying the stabile electrode to the abdomen and the labile hand-sponge to the erector spinæ muscles on the side of the convexity, pass it up and down with firm pressure. Continue five to eight minutes.

Atonic Constipation.—Use slow sinusoidal or a similar current. Apply a large stabile electrode to lower dorsal and lumbar spine, or use a rectal electrode. Move handle-sponge electrode slowly about over abdomen. Time, five to ten minutes.

Gastrectasia.—For simple atonic dilatation of the stomach, use faradic or sinusoidal electricity by means of the intragastric electrode, having patient drink water before swallowing the electrode. Move small sponge electrode about over stomach area or place a second stabile electrode to middorsal spine. Time, four to six minutes. If the intragastric electrode occasions too much disturbance, place the indifferent electrode to the middorsal spine and move a sponge electrode about over the upper abdomen. Time, five to eight minutes.

QUESTIONS FOR REVIEW

1. What are the essentials of a stabile electrode?
2. What are the precautions to be observed in administering the galvanic current?
3. What principles are involved in the treatment of hemiplegia, insomnia, sciatica?
4. Explain the advantage of the galvanofaradic current over the faradic alone for nerve degeneration.

CHAPTER IX

ELECTRODIAGNOSIS

As a consequence of injury or disease the nerves and muscles undergo certain changes, chiefly degenerative in nature. By means of changes in the response to various forms of electric stimulation, electrodiagnosis seeks to determine the stage and degree or severity of such lesions, and by a single test or a series of tests, applied at intervals, to determine the probable outcome—*i. e.*, the possibility of regeneration.

True reaction of degeneration occurs only in injury to the motor nerve or the ganglion cells in the anterior horn from which it originates. It never occurs in a cerebral or spinal lesion which does not involve the anterior cornua. It is, therefore, present in anterior poliomyelitis, myelitis involving the motor cells, toxic neuritides, surgical or accidental division of a motor nerve, involvement of a nerve trunk in callus, or much prolonged compression from other causes, in syringomyelia, amyotrophic lateral sclerosis, etc.

Reaction of Degeneration.—The response of normal nerve and muscle to galvanic stimulation has already been discussed in Chapter V. The normal amplitude of

contraction with the same strength of current is expressed by the formula—

$$CCC > ACC > AOC > COC$$

The first letter of each abbreviation refers to the active electrode—*i. e.*, the one over the motor point (Figs. 55, 56). The second and third letters designate the contraction produced by the make (C C or closing contraction) and by the break (O C or opening contraction). Beginning with a weak current and gradually increasing its strength, the C C C appears with 0.5 to 1 ma. of current; the A C C with 1 to 2 ma.; the A O C with 2 to 2.5 ma., and the C O C with 15 ma.

When the reaction of degeneration appears in its entirety and is said to be typical, the contraction produced is tardy in appearing, is sluggish, and of a progressive or worm-like nature. With these changes, which are the most important features, there appears an inversion of the galvanic formula as follows:

$$ACC > CCC > AOC > COC$$

i. e., the anodal closure contraction is greater than the cathodal closure contraction. These changes constitute the *reaction of degeneration*, or R. D.

In reaching this state of response (R. D.) to electric stimulation in a lesion producing degeneration of a motor neuron the nerve and muscle undergo the following changes:

(*a*) Immediately after injury:

Nerve { Faradic irritability—increased.
Galvanic excitability—increased.

Muscle { Faradic irritability—decreased.
Galvanic excitability—decreased.

(*b*) Degeneration established:

Nerve { Faradic irritability—lost.
Galvanic excitability—lost.

Muscle { Faradic irritability—lost.
Galvanic excitability—increased with inversion of formula. A gradual change to galvanic hypo-excitability occurs with sluggish contractions.

(*c*) Complete death of nerve:

Nerve { Gradually a complete loss of excitability at the motor point.

Muscle { Longitudinal reaction remains—*i. e.*, excitability at distal extremity of muscle. Finally, the muscle dies and all excitability disappears.

(*d*) Recovery { A gradual return to normal reactions takes place.

If degeneration is only partial, the electric reaction will not show full R. D.

Following the complete severing of a nerve trunk, the first stage (*a*) of increased irritability in the nerve lasts three or four days; this declines, passing the normal

about the sixth day and reaching the second stage (*b*) about the tenth day.

In the muscle faradic excitability decreases from the beginning, while galvanic excitability first decreases,

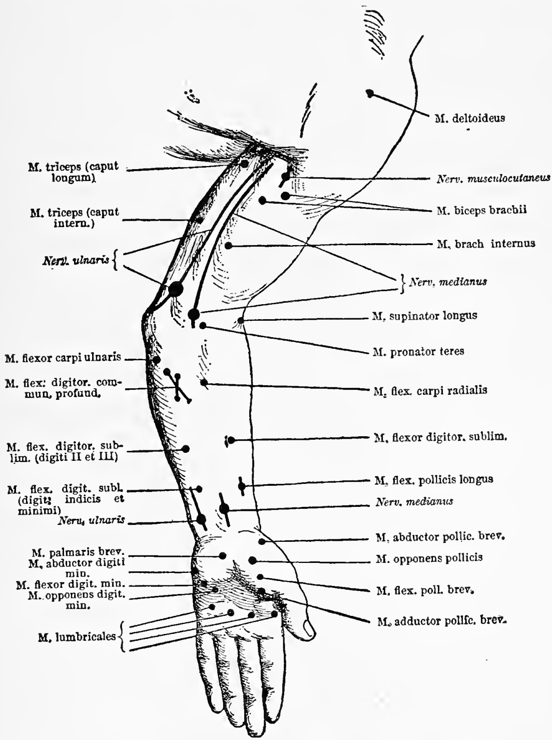

Fig. 55.—Motor points in upper extremity.

with a rather abrupt increase in less than ten days. This stage of increased galvanic response, with inversion of formula and sluggish contractions, may persist for a considerable time.

Motor Points.—In moving a small electrode about over the surface of the body certain points are discovered at which the electrode should be placed in order

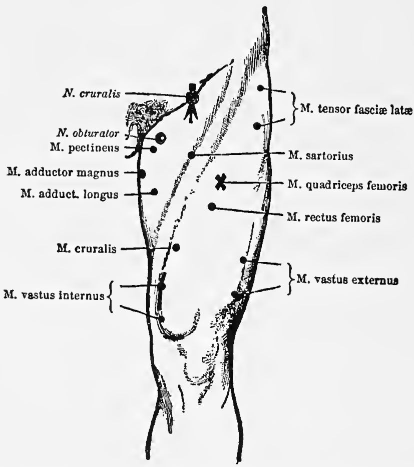

Fig. 56.—Nerves and motor points in lower extremity.

to produce maximal contractions. These are designated as motor points. Those of the inner side of the arm and the front of the thigh are shown in Figs. 55 and

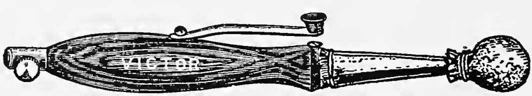

Fig. 57.—Diagnostic electrode. (Erb.)

56. Naturally these are the points where the nerves are nearest the surface or at which they enter the muscles.

Electric Testing.—The active electrode should be small, ½ inch or less in diameter, and should be supplied with a make-and-break key (Fig. 57). The in-

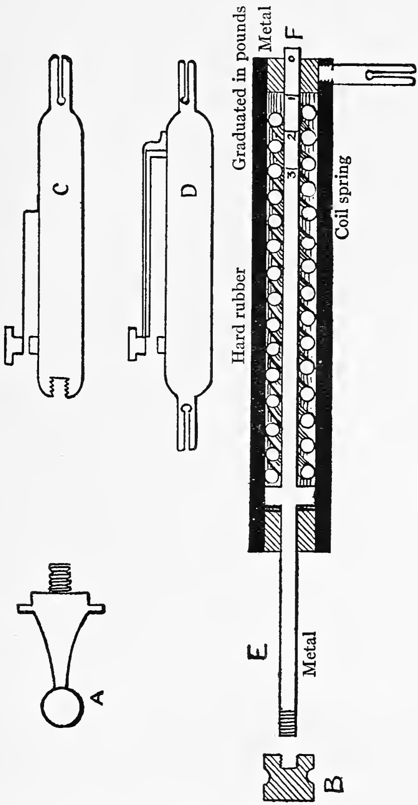

Fig. 58.—Tousey's spring electrode.

different electrode should be larger and be applied to some area having few motor points—*i. e.*, an indifferent area, such as the abdomen, buttocks, soles, and palms.

The active electrode should be covered with sponge or, better, chamois skin. It should be wet with a solution of salt or sodium bicarbonate, and held on the motor point with even pressure, about $1\frac{1}{2}$ pounds, which pressure must be uniform for all points tested if the results are to be of practical value. For this purpose Tousey's spring electrode (Fig. 58), with separate interrupting key, has a definite advantage.

Beginning with zero the galvanic current is gradually increased, while the current is repeatedly made and broken. This is continued until a closure contraction (C C C) is produced, when the polarity is reversed. If the current must now be increased to produce A C C the formula is normal, but if the contraction (A C C) exceeds that produced with the negative pole (C C C) the formula is reversed, and R. D. exists, provided other essential phenomena are present—*i. e.*, the qualitative changes, such as tardy and sluggish worm-like contraction.

Accurate measurement of the quantitative changes in faradic excitability can be satisfactorily made only with a mechanical interrupter, such as that of Leduc, in the primary circuit instead of the usual electromagnetic vibrator. With such an apparatus Leduc has worked out a table showing the duration of impulse and the voltage required to produce muscular contraction.

For quantitative changes in the galvanic response of different nerves, Stintzing's table should be consulted:

STINTZING'S TABLE FOR GALVANIC SCALE OF NEURO-MUSCULAR EXCITABILITY IN MILLIAMPERES.

Nerve.	Average.
1. Musculocutaneous	0.17
2. Spinal accessory	0.27
3. Ulnar	0.55
4. Peroneal	1.10
5. Median	0.90
6. Crural	1.05
7. Tibial	1.45
8. Mental	0.95
9. Ulnar	1.60
10. Zygomatic	1.40
11. Frontal	1.45
12. Radial	1.80
13. Facial	1.75

Hypo-excitability to faradic and galvanic currents occurs in old hemiplegia, slight neuritis, locomotor ataxia, and a few other conditions.

Hyperexcitability to faradic and galvanic currents occurs in recent hemiplegia, lateral sclerosis, chorea, tetanus, and early in locomotor ataxia.

Myotonic reaction occurs only in Thomsen's disease (congenital myotonia). All contractions are slow in appearing, but are tetanic and prolonged.

Myasthenic Reaction.—Single shocks of direct current produce a normal response, but a tetanizing current rapidly produces fatigue. It occurs in a number of conditions allied to myasthenia gravis.

Longitudinal reaction, or the reaction of Remak and Doumer, is a condition in which the muscular response from stimulation at the motor point is slight or entirely lost, while stimulation at the distal end of the

muscle still evokes a contraction. It may be present even in old paralyses where all other responses are lost.

Treatment.—As shown in the latter part of Chapter VII, some form of current characterized by a sine curve is most beneficial in the treatment of degenerated nerves and for neuromuscular massage. Perhaps the best of these currents is a combination of the faradic and galvanic currents modified by a rhythmic rheostat and pole changer. This not only evokes a muscular contraction closely simulating the normal, but also gives trophic effects of great benefit.

CHAPTER X

STATIC ELECTRICITY

STATIC electricity differs essentially from current electricity, as has already been explained. Produced primarily by friction, its amount may be augmented by

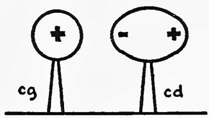

Fig. 59.—Charging by conduction.

influence or induction, which is necessary in order to produce sufficient for practical purposes.

When two dissimilar bodies are rubbed together, one becomes charged with positive, the other with negative,

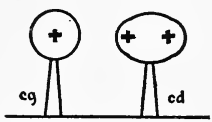

Fig. 60.—Charge remains permanent after removal from charging body when charge is produced by conduction.

electricity. Non-conductors are best for this purpose, but conductors will retain a charge if insulated. A charged body may produce a charge in another body

in three ways—(1) by conduction; (2) by convective discharge or spark; (3) by induction. The first two are essentially contact methods, and produce a charge of like nature which remains permanent in an insulated body after removal from contact with the charging body or sparks from it (Figs. 59, 60). When charged

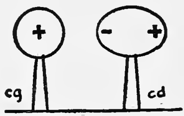

Fig. 61.—Charge by induction.

by influence (proximity, induction) the insulated body shows opposite electricity on its near side and similar electricity on its far side (Fig. 61), but again becomes neutral on removal from the neighborhood of the charging body. If, however, it be touched by a conductor

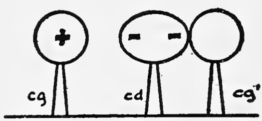

Fig. 62.—Induction charge as altered by contact with conductor.

while under the influence of the charging body it loses its electricity of similar sign (Fig. 62), and now, if removed from the neighborhood of the charging body, retains its (induced) charge of opposite sign (to that of the charging body) (Fig. 63). The operation of static or influence machines depends on these principles.

When two insulated bodies are separated from each other by a dielectric, and are then charged oppositely by contact with charging bodies, these dielectrically separated bodies are given a much heavier charge than would otherwise be the case, because of the attraction

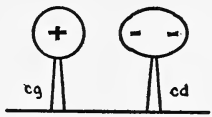

Fig. 63.—Induced charge permanent after induction and contact with conductor.

of the two opposite charges for each other exerted across the dielectric (Fig. 64). This condenser principle is the basis of the Leyden jar (Fig. 65). It consists of a glass jar coated on the inside and outside with tinfoil to one-third or one-half of its height, and having a brass rod stuck through its cap, which rod bears on its inner end

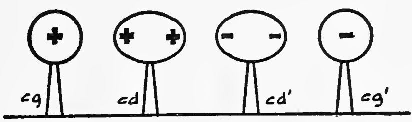

Fig. 64.—Principle of condenser charge.

a chain which makes contact with the inner coating of tinfoil. If by contact of the brass ball with a charging body the inner coating becomes charged while the outer is grounded, a heavy charge of electricity of the same sign as the charging body becomes bound on the

inner coating. If this charged Leyden jar be held in one hand, while with the other hand the brass ball be

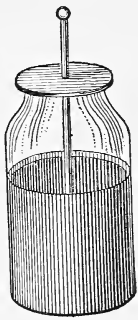

Fig. 65.—Leyden jar. (Harris.)

approached, a heavy discharge will occur accompanied by a spark (Fig. 66). This spark represents millions of

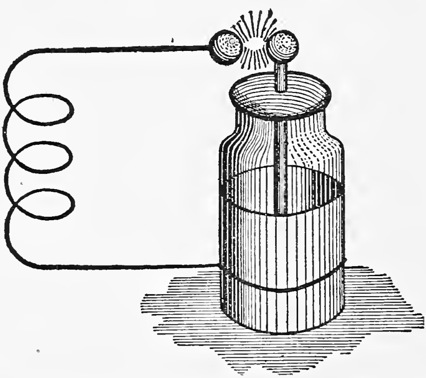

Fig. 66.—Spark between conductors from inner and outer coating of Leyden jar showing charges of opposite sign.

to-and-fro discharges or oscillations. It is this enormously high frequency of oscillation that gives the name

to another form of derived electricity which we shall study later.

Static Machine.—Of modern static machines there are three principal types—viz., the Toepler, the Wimshurst, and the Holtz. The first two are self-exciting, by virtue of the friction brushes with which they are provided. The latter must be excited when it is started, but, once charged, it produces a heavier charge than either of the self-exciting machines.

The Toepler static machine consists of a series of couplets of stationary and revolving plates. The plates are usually made of glass, but may be made of pressed mica or paper. The revolving plates are driven at a high rate of speed by an electric motor. One having sixteen revolving plates, 30 inches in diameter, all enclosed within an air-tight glass case, and kept free from dust and moisture, is powerful enough for all ordinary purposes. Each half couplet of plates is made up of one stationary and one revolving plate. The stationary plate is a little larger than the revolving plate, and has pasted upon the back of it two strips of tinfoil and paper, as shown in Fig. 67. These are called the field-plates. The revolving plate is placed at a very small distance from the stationary plate—as close as it can be and revolve freely. It bears upon its face—*i. e.*, the surface farthest from the stationary plate—six or eight small metal carriers, disc or wedge shaped. These are pasted upon the revolving plate

equidistant from each other. The revolution is in a direction opposite to the hands of a clock. Connected with each field-plate, and fastened over the revolving plate where it enters the influence of the former, is a wire brush, so placed that it rubs the metal carriers as

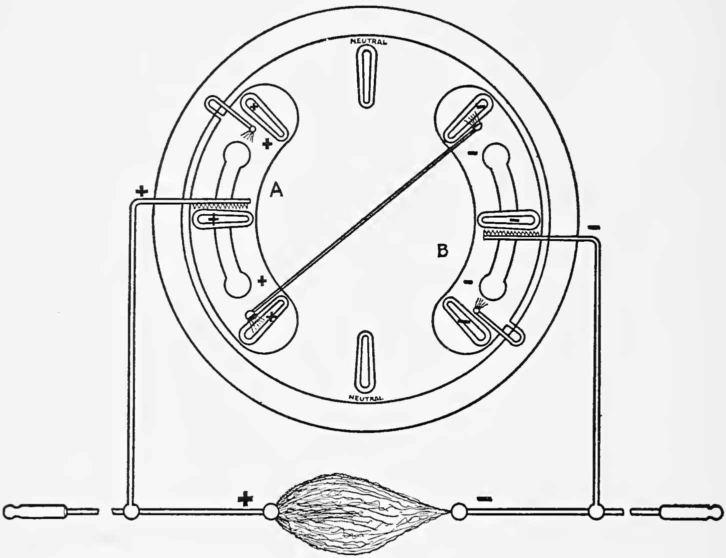

Fig. 67.—Drawing of Toepler static machine: A and B, Positive and negative field-plates pasted on larger (stationary) plate.

they pass under it. This is the appropriating brush. The carriers are rubbed by another brush at the point where they leave the influence of the field-plate. This latter brush is connected by a rod, with its mate over the other field-plate at a point exactly opposite. These are the neutralizing brushes and rod. They serve to main-

tain the two field-plates at opposite polarity. A collecting comb is fastened over each revolving plate at about the midpoint of the field-plate and in the line of the horizontal diameter. These combs are insulated from each other and all other parts, and serve to carry the charges of positive and negative electricity out through the front of the glass case to the accumulating balls and prime conductors on the front of the machine.

While the exact manner in which the static machine operates in the production of an electric charge seems not to be fully understood, yet the following explanation may serve to elucidate the main principles. Field-plate *a* has a slight charge of positive, and field-plate *b* a slight charge of negative, electricity. As a carrier passes under the collecting brush this charge is increased by friction, or possibly, more correctly speaking, it is originally produced by this friction. Since by contact the carrier will bear a charge similar to that on the brush of the field-plate—*i. e.*, a positive charge—this charge is repelled by the field-plate, when no longer in contact with it through the brush, and by a convective discharge the positive charge of the carrier is taken up by the collecting comb as the carrier passes under it. Where this carrier is brushed by the neutralizing brush it loses its residual charge by neutralization with that of the carrier exactly opposite, which latter carrier bears a negative charge and comes in contact with the other neutralizing brush at exactly the same time.

The procedure is similar on the opposite side of the machine, but the charges are opposite in sign because of the opposite charge of the field-plate on this side.

The Wimshurst machine is shown in Fig. 68. In its simplest form it consists of two revolving plates rotated in opposite directions. These bear on their sur-

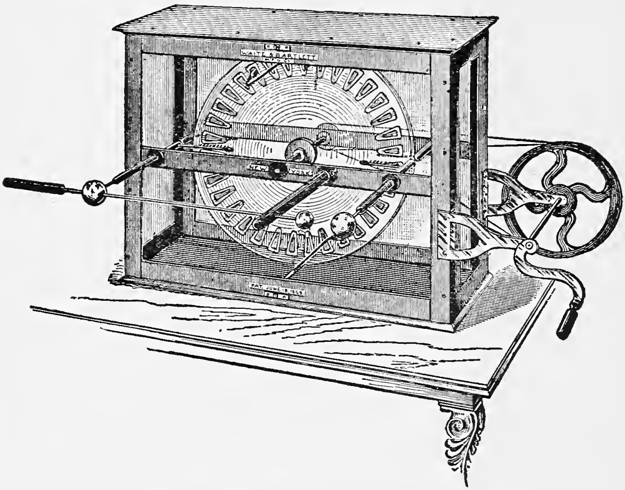

Fig. 68.—Wimshurst machine

faces farthest from each other many carriers. Each plate has its own neutralizing rod and brushes set similarly to those in the Toepler machine. A double comb at each side of the machine collects the charges from both plates. The carriers are excited by the friction of the neutralizing brushes, and when charged act upon those of the other plate by induction, so that a heavy

charge soon accumulates upon the prime conductors. The Wimshurst is self-exciting, and is frequently employed to charge the Holtz machine, being placed in the same case with it and operated by hand.

In the Holtz machine (Figs. 69, 70) the stationary plate consists of two oblong pieces of glass fastened

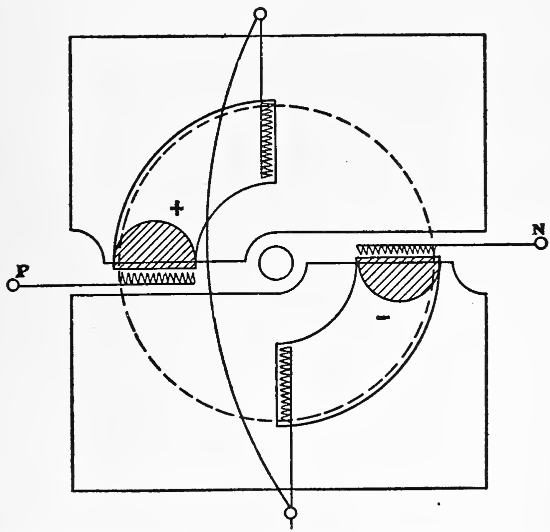

Fig. 69.—Drawing of Holtz machine: P, Positive prime conductor; N, negative prime conductor; +, positive field-plate; —, negative field-plate.

to the case of the machine and insulated by hard-rubber clamps. The revolving plate is without carriers. There are two large field-plates, each extending over a segment one-fourth the circumference of the revolving plate. Each one has a half circle of sheet metal covering it

at the end, where the revolving plate enters its field of influence. At this point the half circle of sheet metal is turned over the edge of the stationary plate. These field-plates and the sheet metal are pasted on the front of the stationary glass plates next to the revolving

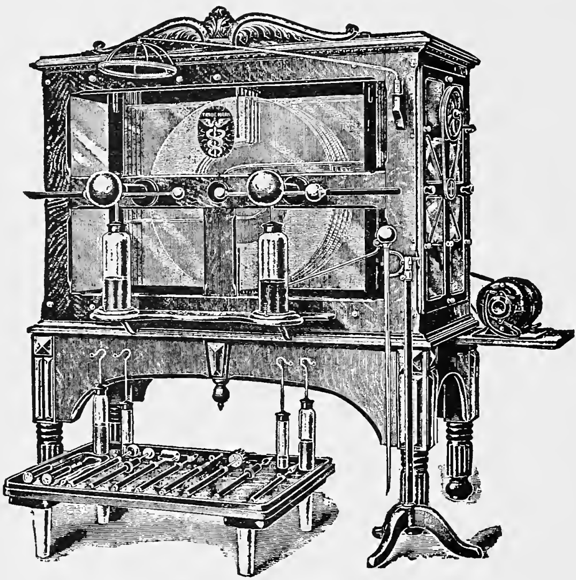

Fig. 70.—Holtz machine.

plate. As in other machines, there are about eight of the couplets of stationary and revolving plates. The neutralizing mechanism consists of combs instead of brushes. They are connected by the neutralizing rod, and are fixed over the revolving plate at the top and bottom where it is just leaving the influence of the field-

plates. The collecting combs from the prime conductors are fastened over the revolving plate at each side where the revolving plate has just entered the influence of the field-plates, near the edge of the metal semicircles. As mentioned before, the Holtz machine is usually charged by a small Wimshurst or Toepler charger. When in good condition it will not reverse its polarity while running.

The case of a static machine should be as nearly air-tight as possible. The interior of the case must be freed from moisture and kept free from dust. To accomplish the former from 2 to 4 pounds of calcium chlorid should be kept in the case in deep containers. This absorbs the moisture, and in the course of time "melts down" and must be removed and renewed. The production of static electricity is unavoidably accompanied by the formation of a fine metallic dust, particles disrupted from the surface of all metals bearing a static charge. Aluminum is less subject to this surface disruption than iron or brass, and also corrodes (oxidizes) less readily under the influence of ozone, which is always generated by the production of static electricity, hence its superiority for metal parts inside the case. Needless to say a static machine operates better in dry weather than in damp weather, inland than near the seacoast, and on the second floor than in the basement.

For administering the static current the following

accessories and electrodes are necessary. An insulated platform, about 2 by 3 feet, having glass legs 8 to 10 inches high; a brass rod 5 feet long, with a brass knob at one end and a hook at the other (the shepherd's crook); a foot-plate of metal and a chair for the platform; several brass chains for making connections; a head

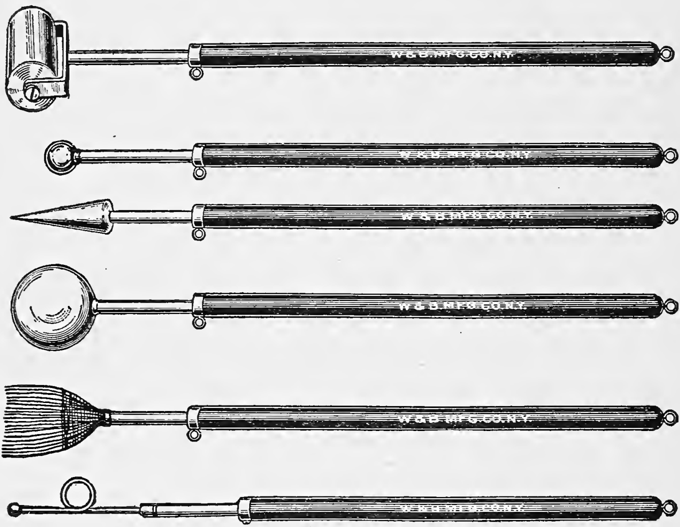

Fig. 71.—Static electrodes.

crown fastened by an insulating pole to the top of the case of the machine or to the wall, or by a cord and pulley to the ceiling; one or more pairs of Leyden jars, so arranged that they can be easily connected with and disconnected from the prime conductors; a mechanism for connecting the outer coatings of these jars. This

latter is usually accomplished by a long swinging arm underneath the base of the machine, operated by a switch pointer. When set to "spark" the jars are connected by this rod, otherwise the outer coatings are disconnected. The electrodes needed are a large and a small metal-ball electrode, a single and a multiple-point electrode (for the latter an ordinary wire-fly bat is the best), a chain holder, and a massage roller (Fig. 71).

General Rules for Administration.—In grounding, connect to a water-pipe or steam-pipe, never to an electric-light fixture, and better not to a gas-pipe. Do not touch the patient or allow any one else to do so while taking treatment. Test for polarity when starting the machine so as to be sure connections will be rightly made. To do this remove all connections and separate prime conductors ½ inch. The positive end is white, the negative violet, with a small white dot next to the prime conductor. If this is not characteristic, separate the prime conductors about 6 inches. The positive end of the spark is now violet and the negative white. By means of a wooden pointer the stream of sparks at the positive end may be led about over the surface of the ball—*i. e.*, deflected. At the negative end no interference or deflection of the stream can be caused by the wooden pointer. Before stopping the machine after a series of treatments it is well to remove all connections and separate the prime conductors. This will leave

the machine charged and may save recharging the next day.

Physiologic Effects and Uses.—Static electricity produces tonic, stimulating, and sedative effects upon the nervous system. It increases oxidative changes and heat production. Certain applications produce muscular contractions; others are strong counter-irritants, and very useful where such an effect is desired. It must be admitted by any careful, candid observer that it is difficult to separate the real or directly physiologic effects of certain applications from the indirect or psychic effects. For this reason the author would recommend certain supposedly sedative applications as a mere accessory to other treatment.

With the positive electrode far enough away to give the sensation of a gentle breeze the effect is sedative. The negative held near the body produces a prickling sensation and is a counterirritant.

The following table gives briefly the technic of the more important static applications, together with their effects and uses. Negative insulation and the negative head breeze as separate treatments have been omitted, as we have never seen any special advantage to be derived from their use, and the latter may cause a violent headache. Each main type of application may be varied in many ways, which will readily occur to the experimenter. For the sake of brevity and clearness only a few of these are given.

STATIC TREATMENTS

Name of treatment.	Method.	Effects and uses.
Positive insulation (Fig. 72).	Patient on insulated platform with feet on foot-plate. Positive pole connected with foot-plate. Negative grounded. Prime conductors beyond sparking distance. Jars off. Modify.—Remove foot-plate or put under chair to lessen effect.	Mild sedative. Insomnia, Neurasthenia, Hysteria, Paralysis agitans.
Positive head breeze or breeze to spine (Fig. 73).	Patient on platform with feet on foot-plate. Negative pole connected with foot-plate. Positive pole connected with head crown or with brush electrode for breeze to spine. Prime conductors beyond sparking distance. Jars off. Modify.—(*a*) Remove foot-plate or place under chair to give milder current. (*b*) Indirect. Ground positive and connect crown or brush with ground to give milder effect.	Feels like a breeze, sedative. Insomnia, Neurasthenia, Hysteria, Nervous conditions generally.
Negative spray (Fig. 74).	Patient on insulated platform. Feet on foot-plate. Positive pole connected with foot-plate, negative with brush electrode (or single point electrode). Prime conductors beyond sparking distance. Jars off.	Stimulating, prickles, counterirritant. Rheumatism, Neuralgia, Sciatica, Lumbago.
Static spark.	Patient on platform and connected with one prime conductor. Ball electrode attached to other prime conductor. Prime conductors beyond sparking distance. Jars on. Switch pointer on spray or spark.	Stimulating muscular contractions, counterirritant. Muscular paralysis, Locomotor ataxia, Lumbago.

STATIC TREATMENTS

Name of treatment.	Method.	Effects and uses.
Static surging or Morton wave current (Fig. 75).	Patient on insulated table or platform. Negative pole grounded. Positive pole connected with roller or sponge electrode and kept firmly in contact with skin. Jars on. Switch pointer on spark. Begin with prime conductors actually touching, separate slowly to distance of ½ inch to 3 or 4 inches.	Deep and painless massage. Resembles sinusoidal. Scoliosis, Lumbago, Paralysis.
Static, induced.	Patient connected with outer coating of one Leyden jar. Sponge or roller electrode connected with the outer coating of the other jar. Switch pointer on spray. Begin with prime conductors actually touching. Separate slowly by screw-like motion to a maximum of ⅛ inch.	Produces a tetanus of muscle. Resembles rapid faradic.
Wave current with vacuum electrode (Fig. 76).	Patient not insulated. Vacuum electrode connected with positive pole. Negative pole unattached, grounded, or one jar on and outer coating grounded. Begin with prime conductors touching, separate slowly.	Counterirritant. Facial neuralgia, Sciatica, Lumbago, Itching.

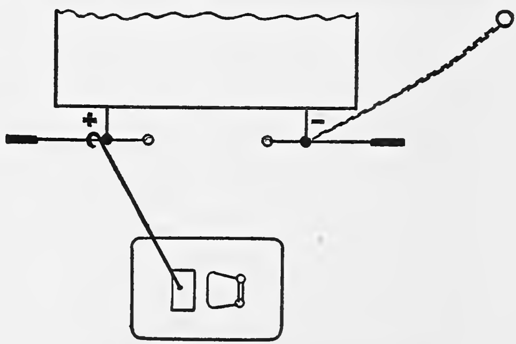

Fig. 72.—Diagram positive insulation.

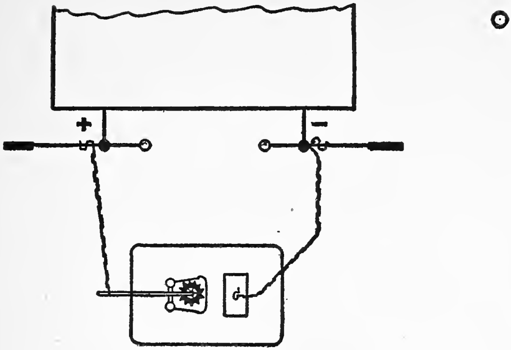

Fig. 73.—Diagram positive head breeze.

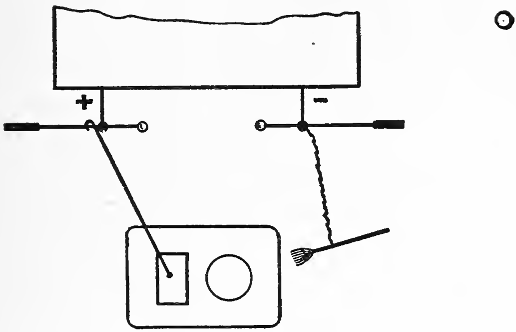

Fig. 74.—Diagram negative spray.

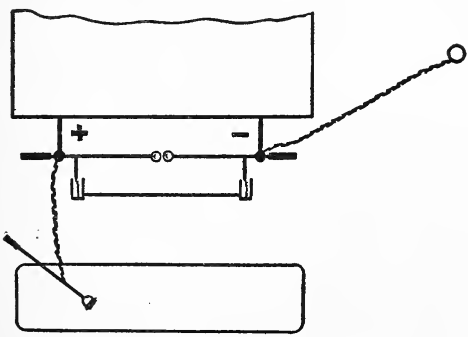

Fig. 75.—Diagram static surging.

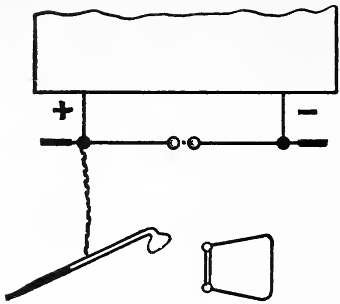

Fig. 76.—Diagram wave current with vacuum electrode.

CHAPTER XI

HIGH-FREQUENCY CURRENTS

From the discussion of the nature of the static spark it will be remembered that a spark is not a single discharge, but a series of to-and-fro oscillations, occurring at the rate of about 500,000 per second. This is true of the discharge between the oppositely charged coatings of Leyden jars attached to the prime conductors

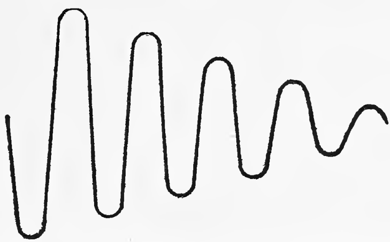

Fig. 77.—Diagram of oscillatory discharge of a Leyden jar.

of a static machine, or of Leyden jars used as the condenser of an induction-coil (Fig. 77). In these discharges the voltage is high, but the amperage is so low at to be almost a negligible quantity—1 ma. or less. On the other hand, its discharge from a high-frequency apparatus possesses an even higher rate of vibration—

millions per second, with a medium voltage and a high amperage—100 to 500 ma. The convective discharge or effluve from a high-frequency apparatus resembles somewhat the negative static spray, but the sensory effects are quite different, chiefly a sensation of warmth in the skin to which it is applied.

There are three fundamental types of high-frequency apparatus—viz., the d'Arsonval, the Tesla, and the

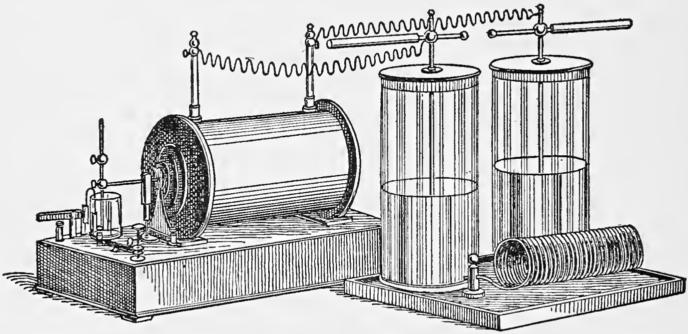

Fig. 78.—D'Arsonval high-frequency apparatus.

Oudin resonator. There are many modifications of these types, but all are constructed upon the principle of one of these three. It is not possible to obtain direct from the static machine or an induction-coil a high-frequency current. The use of a vacuum-tube electrode attached to the static machine does not produce a high-frequency current nor is the application one of violet light. Whatever effects are produced are due to the static wave current, not to violet light or a high-frequency current.

The original high-frequency apparatus is that of Prof. d'Arsonval (Figs. 78, 79). It consists of two large Leyden jars, the inner coatings of which are connected with the terminals of the secondary coil of an ordinary induction-coil, such as an *x*-ray coil. This is itself a step-up transformer. There are sliding rods connected with the tops of the Leyden jars similar to

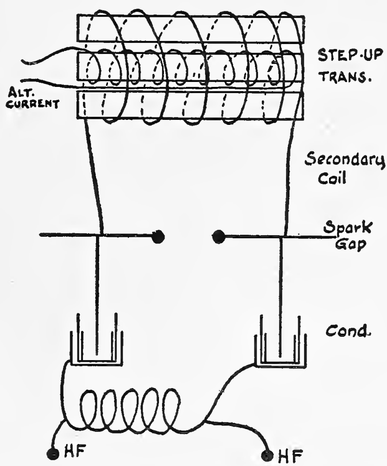

Fig. 79.—Diagram high-frequency apparatus.

the prime conductors of a static machine. These regulate the spark-gap, and hence the strength and frequency of its discharge. The outer coatings of the Leyden jars are connected by a coil or solenoid of heavy wire of about twenty turns, $\frac{1}{2}$ inch apart. No insulation is used on the coils. The patient is treated from connections at one or both ends of the solenoid. If from an

electrode attached to one end only, the method is unipolar; if from attachments at both ends, bipolar.

If the current supplying the primary coil of the induction-coil is a 110-volt alternating current no further apparatus is necessary, except a rheostat for controlling the strength of the primary current.

The strength of the high-frequency current applied to the patient is regulated by this rheostat in the primary circuit of the induction-coil, and by the length of the spark gap between the prime conductors of the Leyden jars. The solenoid of coarse wire and few turns between the outer coatings of the two Leyden jars is the essential part of every high-frequency outfit.

The jars discharge in an oscillatory manner, both across the air-gap and through the solenoid, and the latter becomes the seat of powerful induction effects both in itself, around it, and in the patient who is attached to its ends—*i. e.*, virtually a shunt. The inductance is of exceedingly high-frequency of vibration, because the resistance of the large wire of the solenoid is so low as to allow of a very free and unimpeded vibratory discharge. If the wire of the solenoid were fine wire, the ohmic resistance would be so high as to dampen or impede the vibration, and hence, greatly lower its rate. That which gives the best idea of the powerful and yet harmless character of the high-frequency current is the experiment of two individuals, each holding by one hand an electrode from the ends of the solenoid,

and between them by the other a wire leading to the connections of an incandescent electric-light bulb. The lamp glows brightly, but the individuals holding it perceive no sensation and receive no harm.

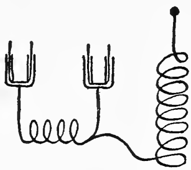

Fig. 80.—Original type of Oudin resonator.

Oudin found that by connecting one end of a very large solenoid (Fig. 80) with one end of the d'Arsonval

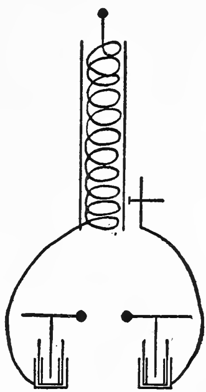

Fig. 81.—Oudin resonator.

solenoid he was able to obtain from the free end of this large solenoid a current very different from the d'Arsonval current. He also found that by varying the point

of contact between the large and the small solenoid, he was able to regulate the discharge of effluve from the free end of the large solenoid. This led him to construct what is known as the Oudin resonator.

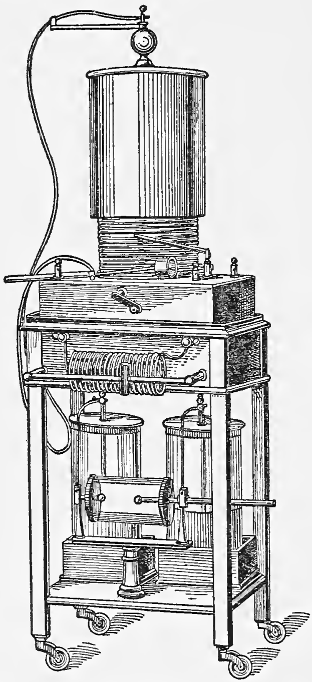

Fig. 82.—Composite high-frequency apparatus.

This consists of a single large upright solenoid (Fig. 81), the lower end of which is connected with the outer coating of one of the Leyden jars. The outer coating of the other Leyden jar is connected with the solenoid by a sliding contact, so that more or less of this coil may

be included in the circuit between the Leyden jars—*i. e.*, make up the small solenoid—while, respectively, less or more of the coil, *i. e.*, the remainder, makes up the large solenoid or resonator proper. The self-induction in the coil increases toward its free extremity, where the tension is so high that a brush discharge or effluve of several inches is given off into the air, and like all convective discharges it becomes more powerful if approached by a conductor, such as some part of the body. The d'Arsonval high-frequency apparatus and the Oudin resonator may be combined in one instrument, as shown in Fig. 82, and the small solenoid of d'Arsonval connected with the large solenoid or resonator. In this case a wire passes from one end of the small coil to the lower end of the large coil, and an adjustable contact on the small coil is connected with the adjustable contact on the large coil. When this is done the lower turns of the large coil virtually become part of the small solenoid.

The resonator is so called because, in order to give off the best affluve, the rate of vibration of its current must be "tuned" to that of the small coil. This is done by the sliding contact. When a patient is attached, the sliding contact must be readjusted in order to bring the resonator again into tune.

The Tesla high-frequency set (Fig. 83) consists of the parts already described for the d'Arsonval apparatus, but in addition it has a winding of very fine wire as a

secondary coil to the small solenoid of d'Arsonval (as a primary), from which it is separated by an insulating tube. Whether the secondary is inside or outside the primary is a matter of indifference. Besides the insulating tube, Tesla also immersed the coils in a liquid insulator of oil to prevent sparking between the coils. The patient is treated from the terminals of the secondary coil. This Tesla transformer produces an extremely

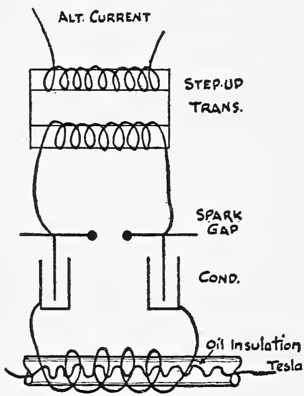

Fig. 83.—Tesla high-frequency apparatus.

high potential as well as a high frequency. It is more commonly used as a part of the outfit for wireless telegraphy than for medical purposes. To produce the Hertzian waves of wireless telegraphy it is used to excite a large coil, virtually an Oudin resonator, whose upper extremity is carried to a high point. This apparatus constitutes the transmitter.

For the medical application of high-frequency cur-

rents the following attachments and electrodes are necessary—viz., an autocondensation couch, a set of vacuum electrodes, a set of cloth-covered metal electrodes of various sizes for diathermy, two metal hand electrodes, an effluve or spray electrode, and a fulguration electrode (Fig. 84).

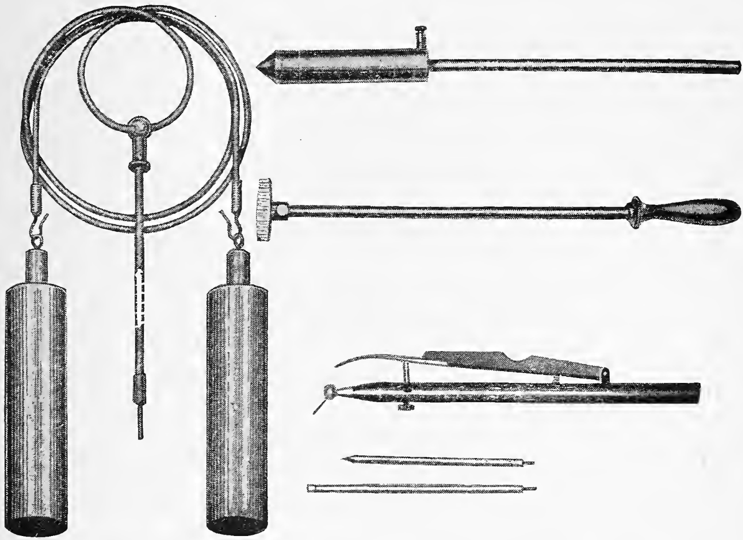

Fig. 84.—High-frequency electrodes (Scheidel-Western *x*-Ray Coil Company).

The autocondensation couch (Fig. 85) consists of an upholstered cushion, or mattress of couch size, and 2 or 3 inches thick, on the underside of which is fastened a sheet of metal slightly smaller than the upholstered cushion. As the patient lies on this couch holding one electrode, with the other connected with the metal

plate, a condenser or Leyden jar is formed. The non-conducting cushion is the dielectric, the sheet of metal constitutes one coating and the patient the other coating of the condenser, hence the term "autocondensation."

Autoconduction is not much used. It consists in placing the patient in a very large solenoid, either

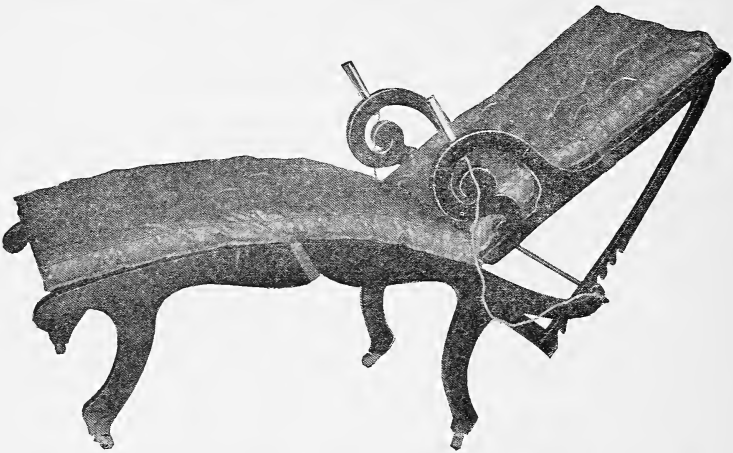

Fig. 85.—Autocondensation couch (Scheidel-Western x-Ray Coil Company).

horizontal, with a couch on which the patient lies, or upright, in which the patient stands or sits. The current received by the patient is generated solely by induction. An incandescent lamp held between his two hands will be brightly illuminated.

In using the Oudin resonator the effluve is applied by means of a brush or special electrode attached to the

upper extremity of the large solenoid and held several inches from the part to be treated.

The glass vacuum electrodes (Fig. 86) are of various sizes and shapes, according to the part to be treated. They are exhausted to the strength of a Geissler vacuum

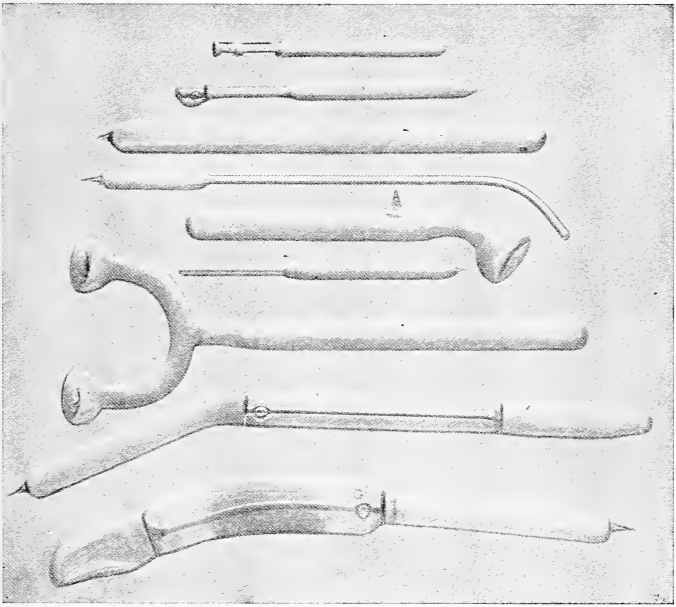

Fig. 86.—Vacuum electrodes.

—*i. e.*, to about one thousandth of an atmosphere. They are held in an insulated handle, to the socket of which is fastened a rheophore from one end of the solenoid. As the other end touches or closely approaches a conductor, such as the human body, the tube glows with a stream of beautiful violet light passing from the socket

or leading-in wire to the point of contact with an external conductor. If held $\frac{1}{8}$ inch or so from the skin, a spray of violet light passes from the glass to the skin and a sensation of warmth is perceived.

To produce the diathermy current a sinusoidal current from an alternating main or a motor generator is stepped up by a step-up transformer to about 1000 volts. This feeds the condenser spark gap and self-induction

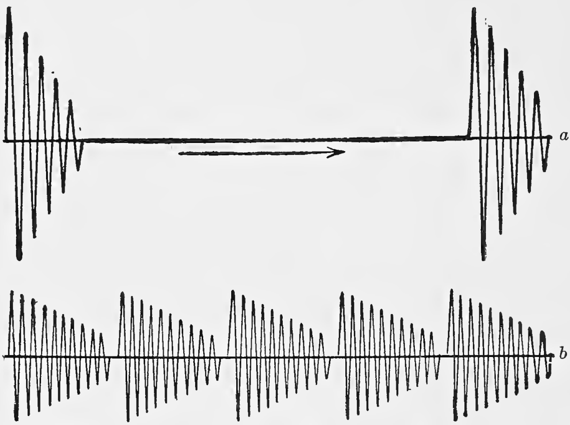

Fig. 87.—High-frequency (*a*) and diathermy (*b*) oscillatory discharges compared. (From Lewis Jones, "Medical Electricity." H. K. Lewis, London, by permission).

coil of an ordinary high-frequency apparatus. The patient's current is taken from a second coil over the self-induction coil in a way similar to the Tesla high-frequency apparatus. Instead of the single spark gap a multiple gap (each one very short) is used. This lengthens the total duration of oscillation, as shown in

Fig. 87. The diathermic current has a low voltage (800) and very high amperage, as much as 3000 ma., in which it also differs from the ordinary high-frequency current, which is of medium voltage and only moderately high amperage, 100 to 500 ma. It generates heat internally in the tissues between the electrodes. This may be carried to the extent of the coagulation of albumin, as shown by the placing of an egg in the circuit between the diathermy electrodes.

For fulguration various electrodes are used. The principle is that of cautery by the electric spark. The end of the electrode is applied near the skin and sparks pass to the part to be cauterized. Small tumors, such as epitheliomata, or lupus ulcers or ulcerated carcinomata, may be treated. The fulguration produces first anesthesia, then softening of the tissues, and finally charring. It may be combined with surgery according to Keating-Hart's method.

The physiologic effects of the high-frequency current are chiefly five—a lowering of blood-pressure, a general increase in oxidation and metabolism, local hyperemia, local analgesic effects, and local heat production on the surface or in deep tissue structures (diathermy). The modalities or methods of application are by autocondensation, autoconduction, brush effluve, vacuum-tube discharges, diathermy, and fulguration.

Name.	Method.	Effects and uses.
Autocondensation.	Patient on autocondensation couch holding one electrode, other electrode connected with metal sheet under insulating mattress. Current, 150 to 500 ma.	Sedative. *Lowers blood-pressure.* Neurasthenia, Functional high blood-pressure.
Autoconduction.	Patient sitting or lying in a large solenoid.	Same as autocondensation.
Effluve spray.	Patient insulated holding one pole—bipolar, or uninsulated and unattached—unipolar; brush electrode attached to end of large solenoid of Oudin resonator.	Generates heat superficially. Vasodilator, Sudorifacient, *Mild counterirritant.* Chronicarticular rheumatism, Sciatica, Diabetes mellitus.
Vacuum-tube discharge.	Unipolar or bipolar method from d'Arsonval or Oudin apparatus.	*Effects same as effluve.* Neurasthenia, Facial neuralgia. Chronicarticular rheumatism, Sciatica, Diabetes.
Diathermy.	Select two padded metal electrodes the proper size for part. Saturate in salt solution and press firmly on skin surfaces of opposite sides enclosing part between electrodes.	Generates heat deep in tissues. Asthma, Sciatica, Lumbago, Pleurisy, Painful joints.
Fulguration.	Patient holds one electrode. Apply sparks to part by fulguration electrode.	Destroys tissue. Epithelioma, Ulcerated cancer, Lupus.

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